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THE WORLD:

OR

FIRST LESSONS

IN

ASTRONOMY AND GEOLOGY,

IN CONNECTION WITH THE PRESENT AND PAST CONDITION OF

OUR GLOBE.

BY HAMILTON L. SMITH, A. M.

SHELL LIMESTONE, FROM THE MOUTH OF THE THAMES.
(From Mantell's Medals of Creation)

"The World is God's Epistle to Mankind."—*Plato.*

CLEVELAND:
M. C. YOUNGLOVE AND COMPANY.
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PREFACE.

The importance of the sciences of Astronomy and Geology, is acknowledged by every one. Few, however, find sufficient leisure to bestow upon these subjects much attention. They look upon the ponderous tomes which men of science have from time to time prepared, with a sort of indifference, as too learned for them. And yet, show any of these, a curious star in the heavens; tell them of the wonders revealed by the telescope; exhibit to them, the impression of a fish in sandstone, or chalk; or show them through a microscope, the curious and distinctive structure of fossil teeth, or the infusoria in a fragment of flint; and they will give willing attention. Since, then, the subjects themselves are so interesting, so profitable, and withal harmless, we have endeavored — with what success will hereafter appear — to supply a desideratum long felt. The object of the present volume is to present in a popular manner, so much of Astronomy, Meteorology, and Geology, as seemed desirable for every one to know. While no pretensions are made to scientific accuracy, yet it is believed that the book will be found worthy of an attentive perusal. There is little to be gained by merely glancing here and there at a page; the knowledge thus obtained, if any, will be small, and soon lost. The attentive reader will, if the book be worth perusing at all, find sufficient to amply repay for the time thus spent. It should hardly be necessary for any one at this late day, to offer an apology in behalf of Geological studies, because of the fancied contradictions to the Mosaic chronology. Writers on this subject heretofore, have spent no little pains, in what we may well term, endeavoring to "make darkness visible." So apologies were once offered for Astronomy, when that noble science taught the diurnal and annual motions of the earth. We have felt called upon to make no such apology, but simply to state the

facts, well convinced that true philosophy and religion go hand in hand, and that if "an undevout astronomer is mad," so must be an undevout geologist. How vast, and how ennobling the ideas of Creative Power and Wisdom, which these sister sciences afford. The mind is overwhelmed by the immensity of creation, whether it strives to reach beyond the faintest and farthest star yet discovered through optic glass, or whether it endeavors to reckon the years elapsed since the first granite rocks upreared their rugged steeps amid the primeval waters. Though we have gazed for whole nights at those dim streaks of nebulous matter in the heavens, at the planets, and revolving stars, when there were companions with us, no longer upon earth; and though we have split open the sandstone shales, and picked out the fossil shells, and looked for hours at little fragments of fossils through the microscope, we do not feel our time as wasted, or wholly spent in vain, if we may be the means of communicating to others a knowledge of these pleasant subjects. However imperfect the execution of our work may be, yet to it we have given long and patient attention. We cannot claim much merit for originality. Among the host of scientific men whose lives have been spent in original investigations, it would be strange could we not find better illustrations than our own; we are still but learners.

Should the present attempt to produce a popular work upon Astronomy and Geology prove successful, it is anticipated following it up with a volume upon the planets and stars; for in the present, only so much of Astronomy is presented as is necessary to understand the motions and general phenomena of our earth. The chapters on fossil remains are not as many as might seem desirable; perhaps we may more perfectly and fully review the same subjects hereafter in another volume.

It is but right to say that the engravings have all been executed in this city by Mr. J. Brainerd; and when we add that they are not from transfers, but from pencil drawings, they will be acknowledged as very creditable specimens of the artist's skill.

Cleveland, August, 1848.

INTRODUCTION.

It would be difficult for us to name a study more interesting than a history of the Earth, past and present; for by a peculiar and distinct chain of causation, it unites the present with the remote past; constantly urges us to look for the beginning of that state of things we have been contemplating; conducts us to the boundaries of physical science, and even gives us a glimpse of the regions beyond.

The Astronomer looks upon the heavens as the type of eternity and immortality. The crystal spheres and orbs which he once imagined to exist, are, so far as stability and uniformity are concerned, now no longer necessary. A few simple motions, results of one law, controled by one Power Divine, sustains the mighty fabric. The Geologist looks upon the heavens and upon the earth as but everlasting; he comprehends that a thousand changes may come over them, while still they move in their grand circles. To him the present configuration of land and sea is but one of the many changes through which the globe has passed, and he is prepared to admit that the whole human race may be swept away, and a new creation succeed; — such catastrophes have occurred. We ask in vain, whether other worlds are inhabited; no voice comes from those distant orbs to tell us of life, no eye can penetrate so far; we turn then with a renewed zeal to study "the science of the changes which have taken place in the organic and inorganic kingdoms of nature," as developed on the surface of our own planet. The beginning; where shall the beginning be? We endeavor in vain to penetrate the almost sepulchral stillness and darkness of the primeval world, and trace with certainty the origin of things. All that we can possibly know is the simple

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THE WORLD.

CHAPTER I.

Figure of the Earth.

"And still, as sunk the golden Orb of day,
The seaman watched him, while he lingered here,
With many a wish to follow, many a fear,
And gazed, and gazed, and wondered where he went,
So bright his path, so glorious his descent." — *Rogers.*

The constant and regular succession of day and night, is the first great phenomenon which arrests our attention, when we commence a study of nature. Day after day, we behold the sun, after a definite and well determined period, rising in the east, and ascending the heavens; and no sooner has the blazing orb sunk beneath the western horizon, than we raise our eyes to the blue vault, expecting and beholding the placid stars.

Doubtless, the first impression is always, that we are at rest, and that the sun, and all the stars of heaven, are slowly, and forever, revolving around us.

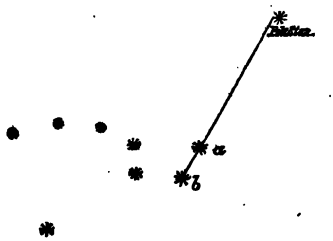
A thoughtful consideration of the phenomena which attend the regular return of day and night, will soon convince us that this conclusion is erroneous, and will point out to us the true solution of the grand problem.

Let us go upon some eminence when evening draws near, and watch the successive changes which usher in the night. The red orb of the sun, shorn of his lustre, his ruddy beams scarce penetrating the mists which creep over the surface of the earth, sinks gradually beneath the wave, or distant hills; a ruddy glow illumines the western sky,

"Twilight's soft dews steal o'er the village green,"

slowly the light fades away, fainter and fainter, giving place to

serene night, and now the stars, which the brilliancy of day had eclipsed, shine forth in all their splendor, and perhaps that fairest one of them all, the evening star, adorns the western sky. As we look over the heavens, we notice here and there a group, or as the astronomer calls them, a constellation, with which we have been familiar from childhood. If we look upon the winter sky, we recognize Orion, with his bright belt, and the Pleiades or seven stars, or turning to the north, the great dipper or Charles' wain, being a part of the constellation "Ursa Major," or the "Great Bear." As the eye wanders over these familiar objects, another sight bursts upon the delighted vision. The full-orbed moon rises majestically over the eastern hills, and in the increasing light, the lesser stars fade away. The evening star, no longer brilliant, is now ready to set below the western horizon, and stars, which at the commencement of night, were to the east of the meridian, are now in the mid heaven. If we turn to the north we find a change there, the cluster or group called the dipper, which we will suppose, at the commencement of our observation was almost parallel with the horizon, as shown in this figure, has moved



eastward, and evidently performed a part of a revolution about some unknown centre. If we prolong our observations we find this group, and all the rest of the heavens apparently revolving around one star, which seems not to move at all. This star is called the pole, or polar star, and is nearly in a line with the two bright stars at the end of the dipper as shown at *a* and *b* in the above diagram, and about five times their distance, from the nearest one. Meanwhile, the lunar orb, with all its beautiful diversity of

light and shade, ascends the heavens, reaches the highest point and declines in the west. Star after star sinks beneath the western hills, and new ones rise in the east. Twelve hours pass away, when again the sun, rising with undiminished lustre, calls the busy world once more into bustle and activity.

The phenomena thus presented, convince us that there is no such thing as rest, for the whole heavens seem revolving around us, and the first step towards an accurate knowledge of our earth is, that either we, or the heavenly bodies, are in ceaseless and regular motion.

Suppose that before us the waters of some vast lake or ocean are spread out; far as the eye can reach there seems to be a place where the sky is resting upon the water, called the *horizon* from a Greek word meaning "to see." As we stand, perhaps wondering how far from us this horizon is, a vessel sails out the harbor and moves steadily from us. Now our first idea is that we are looking out upon a vast plain, and consequently we expect to see the vessel as it moves away, become fainter and fainter, until at last the straining eye will fail to catch the minute image. This appearance is shown in the engraving below.

Instead of this, however, a new and unexpected phenomenon greets the eye. The vessel sails away, and soon arrives at the horizon, and then slowly sinks from view. First the hull disap-

pears, then the sails, and at last the flag, presenting the appearance shown in this engraving.

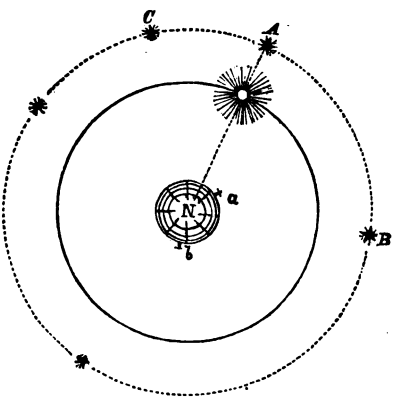
This then is the second step towards obtaining an accurate knowledge of our earth, and we learn that the surface of our lakes, and seas, is not an extended plain, but curved. If we were on a vessel at sea, we would perceive the horizon encompassing us like a vast circle, of which, we would be the centre. And in whatever direction we made an observation, we would find the surface of the water curving or bending from us in that direction. The same phenomenon is observed on land. If we ascend some high elevation, such as a mountain, or lofty monument, the horizon appears in every direction equally distant, or, in other words, a large circle, of which we are the centre. From this we rightly infer that the surface of the earth is convex, like the surface of an apple, or an orange. It becomes an interesting question, after the convexity of the earth is thus established, to determine its actual shape, whether it is a true sphere, or a spheroid, *i.e.*, having the diameter through one direction longer than another, or, whether the curvature is of such a nature as to return into itself, for it is well known that there are curves, such are the parabola, and hyperbola, which, however far continued, never return into themselves like the curve of a circle. It was therefore a bold undertaking to circumnavigate the globe and thus demonstrate its spherical form, by actually sailing around it. This was accomplished however by Ferdinand Magellan, or rather by the expedition which he fitted

out, for he himself did not live to witness the complete triumph of his bold attempt. Magellan was a Portuguese who had entered into the service of Spain. In the year 1519 he sailed for South America, and discovered the straits called by his name, and which separate the island of Terra del Fuego from the continent. He likewise discovered the Marian and Phillipine islands, which he took possession of in the name of the King of Spain, and was killed on one of the latter group. His fleet was mostly dispersed, but one ship with eighteen men, returned to Spain in 1522, having sailed westward completely around the world. The rotundity of the earth, by these means, was established beyond a doubt, though indeed this proof was not necessary, a great variety of phenomena giving the same result. For example, the shadow of the earth, which is cast upon the moon at the time of a lunar eclipse, is always bounded by a curved line or circle, and it can be shown mathematically, that a spherical form is absolutely necessary for the stability of the earth. The moon, and all the planetary bodies, are also observed to present discs, the same as a ball suspended in the sky. Having learned these two things, viz: that there is a great and unceasing motion somewhere, and that the earth is round, it becomes interesting to determine its actual size, its diameter and circumference. Previous to determining this and on the supposition that our earth is the grand centre of the universe, let us study the phenomena presented by the sun, planets, and stars in their apparent *diurnal* or daily revolution around the earth, premising however, that to certain directions upon its surface the arbitrary names, North, South, East, and West, have been assigned. For example, we call the part towards the north star north, the opposite south, and facing towards the north star, we call the right hand east, and the left hand west. These names are entirely arbitrary, *i. e.*, they do not actually represent fixed directions in space, but are simply relative expressions, thus, what is east to one observer, may be west to another, for example, take the next diagram, representing the earth as round, the north pole being at the position N, and suppose two observers one at A, and the other at B, both facing towards the north.

If questioned about some object C, B would declare it to be

west, being at his left hand, whilst A would assert it to be east,

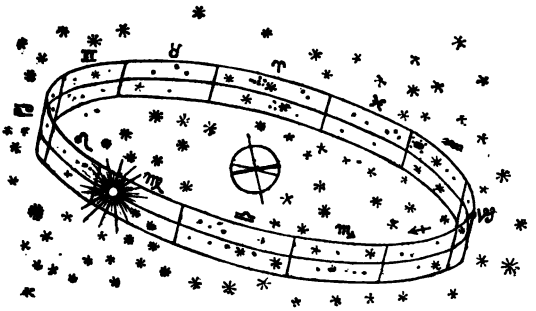
being at his right hand. The terms therefore, north, south, east and west, are only relative expressions, and not absolute directions. It will be necessary to remember this, and we may also remark, the same is true of the expressions up, and down. What would be up to an observer at A, would be in the direction N A, but this would be down to an observer at B. Hence we must learn to consider up, as away from the earth, and down as the direction to its centre, and therefore not absolute directions in space but only relative terms. Now as the sun and the stars are observed after certain regular intervals to appear in the east, apparently move over the heavens, and set in the west, the natural inference is, that they are revolving in vast circles around the earth, which itself is the immovable centre. Below we have given



an engraving which represents the earth as the centre, and the

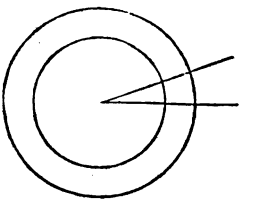
sun revolving around it in a circular orbit, and the stars still further beyond. Now on the supposition that this is the true system of the world, suppose the sun revolving in the direction A B, and an observer at *a*, facing towards the north N. He would perceive the sun appear to rise at his right hand, or in the east, and when the sun had travelled far enough round, say to B, to become visible to an observer at *b*, he would see it at his right hand, or in the east. The sun in his daily revolution, would thus track out in the heavens a certain line, which astronomers call a diurnal circle. Now suppose that some morning, just at sunrise, we observe a particular star, A, close to the sun, rising just before it. If the stars revolved around the earth in the same time as the sun, as they seem to do from a casual observation, it is evident that after any definite interval, say one month, the sun and this star would still be found together, but this is not the case, for after one month, it will be found, that this star A, which rose just before the sun, will now rise two hours before him, and the sun will be near the star C, having apparently moved backward the distance A C. If we should continue to observe this backward motion of the sun, we would find that after one year had elapsed, the sun would have moved completely around backward, contrary to the direction in which, each day he seems to move across the heavens, arriving again at A. Hence it would appear, that, the earth being the centre, the stars are revolving around it a little faster than the sun, but in the same direction, gaining upon the sun about 4 minutes a day, so that in one month the star A would gain 120 minutes or two hours, and rise just so much sooner than the sun; and thus, in the course of a year, the stars would make one more revolution than the sun. Now suppose we were to observe carefully the stars near and over which the sun passed in this backward motion, for it is evident that this path would mark out a circle in the heavens. Astronomers have done this, and they call this path or line, which has a fixed position among the stars, the *Ecliptic*, or sun's path. On the next page we represent the ecliptic, and a certain space on each side of it. This space includes the orbits of all the planets, which also partake of the same backward motion as the sun.

not moving on uniformly with the stars. The middle black line



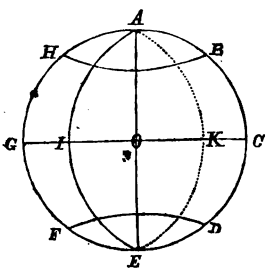
represents the ecliptic and the whole space or belt is called the *Zodiac*. The ancients divided the zodiac into twelve equal parts, and gave them names, indicative of the peculiar employment of that season of the year, when the sun happened to be in any one of them. For example, the sun, in the preceding diagram, is in the sign called Virgo, or the Virgin; this sign was represented by a virgin bearing sheaves of wheat, as the sun was near these stars in the fall of the year, when the harvest was gathered. We shall refer to this again when we explain the phenomena of the seasons. The ecliptic was divided into twelve parts, or signs, because the moon makes the complete circuit in one-twelfth of the time the sun does, hence the twelfth of the year is called a moon, or a month. The time of a lunation, or interval from new moon to new moon, being thirty days, and twelve of these lunations happening in a year, the number of days to the year, when reckoned by lunar months is 360. This number of days however is not strictly correct, for the sun makes 365¼ revolutions apparently, around the earth, while moving from any particular star around to that star again. It would be inconvenient to subdivide the ecliptic into 365 parts as this number cannot be halved, or quartered. So the early astronomers, adopting the lunar year, divided the whole circle into 360 parts, which they called degrees. This division, it will be understood from what we have said, was

perfectly arbitrary. The circle might have been divided into just 100, or 1000 parts, and these called degrees, but it was convenient to adopt for the length of a degree, a space which would represent the progress of the sun in one day as nearly as was possible. When we speak of a degree, it must be remembered that an absolute length is not meant, but only the 1–360 part of some circle. The length which belongs to a degree will vary with every different circle. Thus in this diagram, we have two circles with



a common centre, and two lines drawn from that centre, including 20 degrees of each circle.

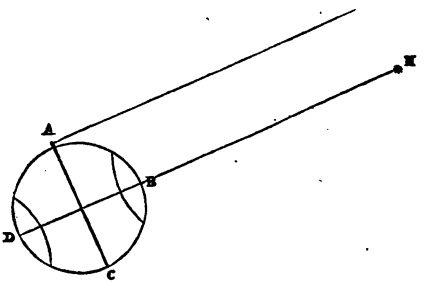
All circles are supposed therefore, to be divided into 360 parts, and the 1–360 part of any circle is called a degree. Two kinds of circles are supposed to be traced on the earth, as also in the heavens, viz, great and small circles; this name does not arise from the fact that one circle is actually greater than another, the distinction is more marked, and is this—



Let A B C D, &c., represent the earth, and let G C be a circle

the plane of which passes directly through the centre of the earth; this is a great circle. So is A E for the same reason, for if the globe were to be divided through these circles it would be exactly halved, but a circle passing through H B, or F D, is called a small circle, since the plane of the circle does not pass through the centre of the sphere on which the circle is drawn. From this definition it will be perceived that the circle A I E K, (the part behind the sphere being shown by the dotted line) is a great circle, because the plane of this circle passes through the centre of the sphere. Every great circle, has what is called a pole, that is, a point ninety degrees, or one quarter of a circle, distant from it in every direction, thus—A is the pole of the circle G C, for from whatever point on the circle G C, the distance is measured up to A, it will be found 90°. For instance the arcs A G, A I, A O, A K, A C, are all ¼ of their respective circles. Now suppose the circle G C, to represent the equator, then A will be the north pole of the earth, and E the south pole. Suppose now this great circle which we have called the equator to be actually traced around the earth and divided into 360 parts called degrees, marked (°), and suppose these degrees subdivided into minutes marked (′), and call these minutes miles, how many miles would the earth be in circumference? Evidently sixty times 360, or 21,600 miles. This is not so much as the circumference is usually stated to be; viz, 24,000 miles, and for this reason; the mile at the equator, is longer than the English statute mile. Referring to the preceding figure, it will be readily perceived that if the circle H B was divided into 360 parts and these again subdivided into 60 parts each, called miles, these miles would be much smaller than the equatorial miles, indeed it would require 69½ English statute miles to constitute 1°, or 60 equatorial, or geographical miles. Now if we take 69½ miles for the length of a degree, it is evident the circumference of the earth will be 360 times this, or 25,020 miles, and as the diameter is a little less than ⅓ the circumference, the diameter is called in round numbers 8000 miles. When therefore we assert that the earth is 8000 miles in diameter, we mean simply this, if the equator, or any great circle drawn upon the

earth, is divided into 360 parts, and these subdivided into sixty parts each, and their length ascertained, that it would take 8000 of them to measure the diameter of the earth. The length of a mile therefore, instead of determining the diameter of the earth, or its circumference, is itself determined by that diameter or circumference. The circle might have been divided into 1000 parts, and these subdivided into 100 each, this would give 10,000 minutes or miles for the circumference, but the mile in this case would be shorter. Having assumed the earth's circumference 24,000 miles, we next desire to know when we have passed over a mile on its surface. This would seem a difficult undertaking at first thought, for how can we determine when we have passed over a degree upon the earth? A diagram will explain the manner this is



accomplished. Let A B C D represent the earth, A C being the equator. A spectator at the pole B, would see the pole star directly overhead, but a spectator at A, on the equator, would see the pole star in the horizon. Hence, in travelling from the north pole to the equator, the elevation of the pole star changes from directly overhead, or in the zenith as it is called, to the horizon, or 90°, changing its altitude 1° for every degree traveled over the earth's surface, either north or south. The astronomer is furnished with the means of measuring the altitude of the pole star, or its distance above the horizon by means of the quadrant, or the astronomical circle which we shall describe, together with some other astronomical instruments in the next chapter. We have

now learned three important facts in regard to our earth, and the celestial bodies, viz: The ceaseless and uniform motion, the rotundity of the earth, and the actual length of a degree upon its surface, and this is no small progress, supposing we commenced entirely unacquainted with the subject. Fortunately, as we proceed to show the gradual improvement in astronomical knowledge, we can also give a history of the science, and briefly notice those eminent men, and their discoveries, whose labors have brought astronomical science to its present state of perfection. Supposing that we are ignorant of the nature of the motion perceived in the heavenly bodies, we will lay aside further observation for the present, and notice some of the instruments employed in astronomical discoveries.

CHAPTER II.

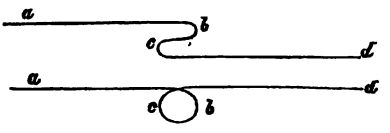
Astronomical Theories.

"He sat and read. A book with silver clasps,
All gorgeous with illuminated lines
Of gold and crimson, lay upon a frame
Before him. 'Twas a volume of old time;
And in it were fine mysteries of the stars,
Solved with a cunning wisdom." — *Willis.*

The imperfect historical records of the nations of antiquity prevent us from determining with certainty when, and with whom, astronomical science had its origin. It is certain however, that it was cultivated at a very early age by the Egyptians, the Chaldeans, the Bramins of India, and the Chinese. In a fine climate, and fertile country, inhabited by nomadic tribes, we can well imagine the sublime spectacle of the heavens to have arrested early attention. At a later period, when the motion of the sun among the stars began to be noticed, and consequently the helical rising and setting of certain stars, *i. e.*, their rising or setting just before or after the sun, became the signs of approach of certain seasons, the stars were grouped into constellations, and fanciful names given to them. Thus we find Hesiod alludes to the helical rising of Arcturus, and Thales mentions the number of days after the vernal equinox, when the Pleiades set just as the sun arose, by means of which we are now enabled to tell the age in which he lived, as will be explained hereafter.

The constellations being located and named, and the sun's apparent path determined in the heavens, astronomers began to observe more carefully the motions of the sun, moon, and planets, among the stars, and endeavored to frame a system of the world which would explain all the apparently irregular motions. It was

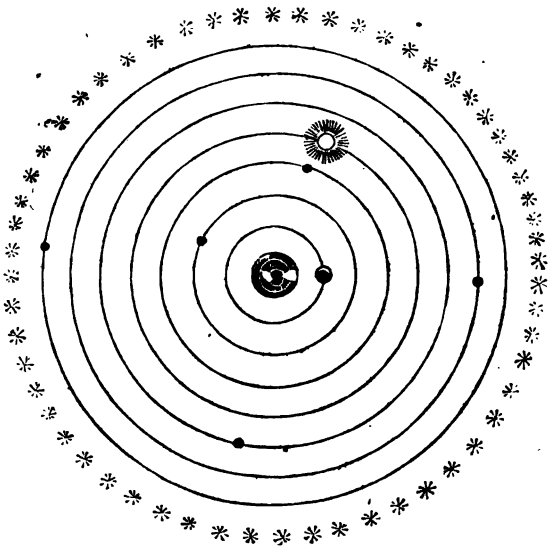
very early observed that the sun and moon moved around the earth with different velocities from the stars, and that there were certain bodies, five in number, which also appeared to be wandering in the heavens, these were called planets, from a Latin word meaning to wander, and were named in order, according to their supposed distance from the earth, Mercury, Venus, Mars, Jupiter, and Saturn. As soon as these wandering bodies were closely observed, certain irregularities in their motion attracted attention, instead of moving uniformly in a circle in the heavens, like the sun, their paths were often broken, and even turned back, as represented by the lines below, moving from *a* to *b* direct, *i. e.*,



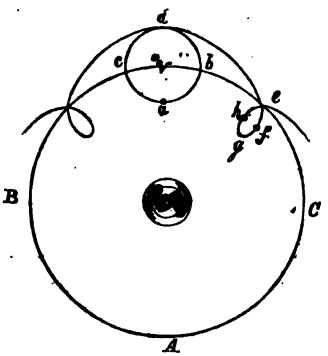
in the order of the signs, from *b* to *c*, retrograde, or contrary to their previous motion, at *b* and *c*, apparently still, or stationary for a short time, and from *c* to *d* moving again direct. In addition to these irregular movements, two of them were observed to always remain in the neighborhood of the sun, viz. Mercury and Venus, while Mars, Jupiter, and Saturn were often seen directly opposite, rising when the sun was setting. Hence, in framing any theory, it was necessary to account for these motions.

All the early astronomers supposed that the earth was the centre of the system, and that all the celestial bodies were revolving around it. The only system of the world which attracted much notice, was that of Ptolemy the great Egyptian king and philosopher, called, from him, the Ptolemaic system. This is the system which we would naturally adopt upon casual thought. Here is the earth occupying the centre, and around it the moon is supposed to be revolving not quite as fast as the sun, next comes Mercury, then Venus, the Sun, Mars, Jupiter, and Saturn, beyond the whole was supposed to be the grand *primum mobile*, a sphere

to the surface of which the stars were all attached, and revolving

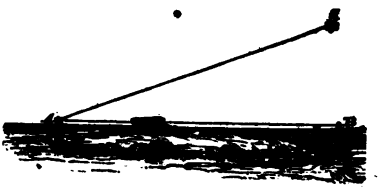


once around the heavens in 24 hours. To account for the irregular motions of the planets before noticed, a modification of this



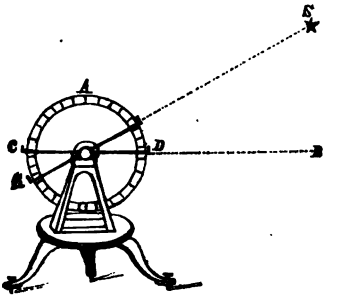
system was necessary. Thus B A C may represent the orbit of

Mercury around the earth, the planet however, instead of revolving in this circle, was supposed to be revolving in another smaller circle *c a b d*, whose centre *v* was carried forward as the circle A B C revolved around the earth, in the order of the letters, the planet moving in the contrary direction in the small circle *c a b d* would apparently describe the curve line *d e f g h*, being stationary at *f* and *h*, and apparently moving backward through the arch *f g h*. Now in order to make Venus and Mercury always accompany the sun, the centre *v* of the small circle, was supposed to be always in a right line nearly, between the earth and sun. Such was the Ptolemaic system, and as it appeared to explain the irregular motions by really uniform, or true circular motions, it was soon adopted as the true system of the world. In the time of Ptolemy astronomical instruments began to be used; for some time previous however, the eastern nations, in order to ascertain the instant of mid-summer, or mid-winter, had been in the habit of measuring the length of the shadow of a vertical gnomon or style, but Ptolemy introduced the use of graduated spheres. We have already observed that all circles are divided into 360 degrees, and these subdivided into 60 minutes each. Hence it is evident that by means of a graduated circle, angular distances may be measured in the sky. An angle, it must be remembered, is simply the inclination of two lines and has no reference at all to the length of the lines, thus S A B is the angular distance of the star



S from the object B. To observe this angle, or inclination, we may use a small graduated circle thus. Let A C D be a circle graduated into 360°, having a moveable index turning on its centre, which index is furnished at each end with a sight-hole. First look with the index towards the object B, and observe the

point where the index marks the circle, say at 10°, then turning



the index towards S, observe where it makes the circle, say 20°, the difference 10°, is the angular distance of S from B. The instruments of Ptolemy were constructed upon this principle though not so perfect, using shadows, and other contrivances, instead of simply observing through two vanes or sight holes.

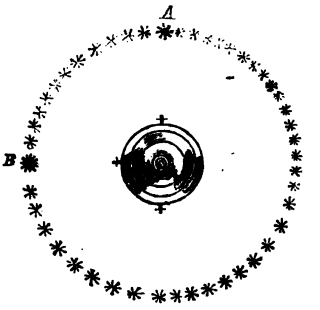
Ptolemy had not intended his system to be received other than an hypothesis, which might account for the observed motions; he did not profess this to be the actual order of the world, but his successors, without their great master's love for truth and careful study, soon gave to these supposed spheres and orbs, a real existence, and the heavens became crowded with crystalline spheres moving in all directions, and with all velocities, and as often as new motions, or irregularities in the old ones were detected, new circles moving at their centres round the old ones, were added, called epicycles, so that at last cycles and epicycles, revolved in all directions, bearing the planets along with them, until amid the crowd of spheres and crystal orbs the brain grew dizzy, and could not comprehend the mysterious revolutions. Amidst all this confusion of "Cycle and epicycle, orb on orb," a bright luminary arose, and with a master hand dashed aside the crystal spheres of the successors of Ptolemy, substituting instead, the simplicity of truth. This man was Nicholas Copernicus. At the time when the true system was about to be made

known, the followers of the Egyptian school were in their glory. Purbach, professor of Astronomy at Vienna, had reviewed the whole system, and by the addition of various new spheres, had succeeded in explaining all the observed irregularities of the planets, and thus silenced forever the sneers of infidels, and particularly those of Alphonso X. King of Castile, who had observed, "Had the Deity consulted me at the creation of the universe, I could have given him some good advice." But the hour of triumph was short. Error, which had sat like a cloud upon the mountain top, overshadowing all below, was ready to vanish before the bright beams of the sun of Truth.

The obscurity which hangs over those early days, conceals the steps by which Copernicus arrived at the knowledge of the true system. It required indeed a bold mind to disregard all the religious dogmas of the time, and methodise a system, which as Tycho Brahe, himself an illustrious astronomer, observes, "Moved the earth from its foundation, stopped the revolution of the firmament, made the sun stand still, and subverted the whole ancient order of the universe." Such a mind however, Copernicus seems to have possessed, although his modesty prevented him from publishing his views, until at so late a period, that he only lived just long enough to see a printed copy of that book which was to gain him immortal honor. At this time, in the words of his admirable friend the Bishop of Culm, "He was occupied with weightier cares"—about to test the reality of that unknown world whose mysteries sages have endeavored but in vain to understand, from remotest ages. The first gleam of truth which burst upon the mind of Copernicus was doubtless the idea that the apparent revolution of the starry orbs around the earth from east to west once in 24 hours, was actually accomplished by a revolution of our earth on its axis in the same time but in the contrary direction. Refer to the following diagram and observe the simplicity of this explanation.

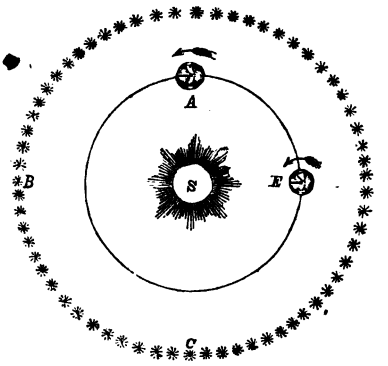
Here is the earth, and around it on all sides the celestial concave. Suppose now an observer situated upon the earth should see a particular star A, directly overhead at sunset, and that the earth was revolving once on its axis in 24 hours in the direction of

the letters A B, after an interval of 6 hours, the spectator would



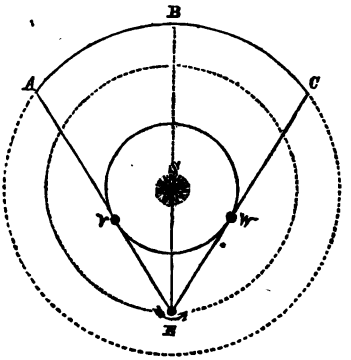
arrive under B, and perceive the star B directly overhead while the star A would be just ready to sink below the horizon. After an interval of 18 hours more he would again arrive under A, having performed a complete revolution. Now as all the stars are observed to have a perfectly uniform motion, moving once around the earth in 24 hours, never changing their apparent positions with regard to each other, doubtless this supposition appeared to Copernicus the most rational, and its truth is now incontestably proved, and universally admitted. The great motion of the heavens being thus shown not to be real, but only apparent, Copernicus naturally endeavored to ascertain how far certain other motions, which the followers of Ptolemy explained by innumerable cycles, and crystalline spheres, as if all their observed motions were real, might be explained by a movement of our earth instead of these bodies. The actual size of the sun and planets, as also their actual distance from the earth, not being known at that time, rendered this problem more difficult, and beside this, he was wholly unacquainted with the laws of gravitation. Hence it was no ordinary effort of mind to reduce the various complicated motions of the planets and the sun to one harmonious system. Pythagoras, the celebrated Greek philosopher who lived 500 years before Copernicus, had already suggested the idea that the sun was the central body, and that the earth and planets were revolving about the sun at various distances. He did not attempt

however to account for the irregularities observed in the planetary motions. Copernicus might have easily perceived, and no doubt did perceive, that the motion of the sun backwards in the heavens, and to which we have alluded, was only apparent, and was due to a real motion of our earth, which may be illustrated thus:



Let S represent the sun, occupying the centre of the system, and E the earth moving in an orbit around it. Now an observer on the earth at E would perceive the sun S, apparently projected against the heavens near the star B. If the earth was stationary, then after 24 hours, turning around in the direction of the arrow, *i. e.*, from left to right, or west to east, (the north pole in the diagram being supposed towards the eye) the sun would again appear close to the star B, and the sun and stars would come to the meridian or mid-heaven together. Now suppose the earth to have moved forward in its orbit to A, and imagine the sphere of stars figured in the diagram to be expanded to an infinite distance, it will be easy to see that the sun and the star B, will no longer come to the meridian together, the meridian being represented by the black line on A, but that, on the supposition that the earth is turning in the direction of the arrow, the sun would come to the meridian, or this line, much later than the star, and would appear among the stars at C. To explain the motions of Mercury, and

Venus, Copernicus supposed them to be revolving around the sun, but in orbits within the earth's. This would explain why they were never seen at any considerable distance from that luminary and also the various irregularities observed in their motions, Thus:



Let S be the sun, E the earth, and V, Venus. In the situation represented in the diagram Venus would appear among the stars at A, the sun being at B. In this case, supposing the earth to turn on its axis in the direction of the arrow, the sun would come to the meridian or overhead, to an observer on its surface, before the planet, which consequently, setting after the sun, would be the evening star. Now supposing the earth stationary in its orbit, let Venus move from V to W. This would cause her to describe the arc A C in the heavens, gradually approaching the sun, which is apparently at B, and then appearing on the opposite side. When in the position W, still supposing the earth to turn on its axis in the direction of the arrow, Venus would come to the meridian, or rise before the sun and consequently be morning star. During the rest of her revolution in her orbit, from W to V she would seem to move backwards in the heavens, or retrograde from C to A, and at the points C and A she would appear for a short time stationary. We have supposed the earth to be at rest,

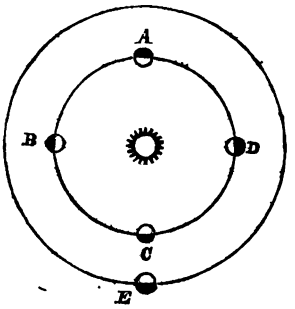
but it really moves in its orbit in the same direction as Venus, though much slower, and the phenomena are the same in kind as though the earth was still. The phenomena of Mercury may be explained in the same manner as those of Venus, but as Mercury is never seen at so great a distance from the sun as Venus, its orbit is placed between the orbit of Venus and the sun. The planets Mars, Jupiter, and Saturn being occasionally observed at midnight, or directly opposite to the sun, their orbits are located exterior to that of the earth, and in the order just named, which is according to their relative velocities.

Such is the simple and beautiful system of the world known as the Copernican system. Long as time will last, the memory of its successful author shall live. His fame as everlasting as the duration of those bright orbs which roll around the sun. Copernicus lived in an age far behind himself, and no doubt refrained from publishing his views to the world from fear of ecclesiastical censure, although indeed he ridicules this idea, and dedicates his book to Pope Paul III, and was induced to publish it by the persuasions of Schuenberg, Cardinal of Capua, and Gisas, Bishop of Culm.

In those days the Bible was not only received as the rule of faith, but as the oracle of nature. To assert the rotation of the earth on its axis, and deny the revolution of the sun around it, was impiety, and direct contradiction to scripture. Joshua commanded the sun to stand still, and therefore the sun must move. So it is said, "The pillars of the earth are the Lord's." And yet no one supposed at that time that the earth was literally sustained on pillars. Sir Isaac Newton himself, would say "The sun rises," "The sun sets," and yet would mean far from asserting that the sun actually moved. The ignorance which repressed the efforts of Copernicus, at a later day crushed the energies of Galileo, who with his heaven-directed tube maintained and demonstrated the truth of the Copernican system.

Referring to the next diagram, it will be seen that upon the supposition that Venus is revolving between the sun and the earth, her disk would assume the phase of our moon. For example when at A she would appear wholly illuminated, her enlightened

disc being turned towards the earth at E. When at B, she would appear half illuminated, as the enlightened hemisphere is now partly turned from the earth. At C, she would appear either wholly unillumined or at best a slight crescent, since her enlightened portion is now wholly or almost wholly turned from the earth, at D, she would appear again half illuminated. These phases were



not really observed in the case of Venus, although Copernicus predicted they would be, when we could see Venus plainer, and this was considered by some as an unanswerable argument against the truth of his theory, while others maintained that the planets shone by their own inherent light, and of course had no phases. Such was the state of science when Copernicus died, but already the dawn of a brighter day was advancing. The use of spectacle glasses was quite common, and many shops were engaged in their manufacture. It is related that some children of a Dutch optician, while playing with the spectacle-glasses one day, chanced to arrange two at such a distance as gave a magnified but inverted image of distant objects, and the optician following out the idea thus accidentally presented, the telescope was first made in Holland. Galileo, at this time professor of Mathematics, at Padua, heard of the wonderful tube, and immediately set himself to work to construct one. In this he was eminently successful, and in his hands it gave the death blow to the opposers of the system of Copernicus. With the telescope, Venus was clearly observed *exhibiting the phases which Copernicus had predicted.*

We cannot imagine the delight which must have thrilled the heart of Galileo when he, for the first time since the creation of man, beheld the phases of the evening star. Already a champion for the true system, he must have hailed this complete and unanswerable evidence, with a joy such as we cannot now conceive. We would have supposed that now the absurd dogma which asserted that the earth was the grand centre of the universe, and denied its diurnal revolution, would have been forever rejected, but alas! error is difficult to eradicate, it takes root easily, and attains a most luxuriant growth, without any cultivation.

Henceforth Galileo's life was embittered by a persecution from the Church. The doctrines which he maintained, and so ably advocated, were supposed to contradict the Bible, and at the old age of 70, after a life spent in the cause of science, he was the subject of a most humiliating spectacle. A hoary headed man, with trembling voice abjuring what he knew to be the truth, abjuring, cursing, and detesting as heresies those doctrines which he had spent the vigor of his manhood in establishing, those eternal and immutable truths which the Almighty had permitted him to be the first to establish, and with his hand on the Gospels, avowing his belief that the earth was the centre of the system, and without the diurnal motion on its axis. Oh! that the strong spirit which sustained the early martyrs for religion, had supported this martyr of science.—But the feebleness of age was upon him, harrassed and tormented, worn out by long persecution, his spirit yielded, and never recovered from the degradation; blind and infirm, he never talked or wrote more on the subject of astronomy. Here are the qualifications of these two propositions which asserted the stability of the sun and the motion of the earth, as qualified by the Theological Qualifiers:

I. The propostion that the sun is in the centre of the world, and immovable from its place, is absurd, philosophically false, and heritical, because it is expressly contrary to the Holy Scriptures.

II. The proposition that the earth is not the centre of the world, nor immovable, but that it moves, and also with a diurna motion, is also absurd, philosophically false, and theologically considered equally erroneous in faith."

It hardly seems credible that such opposition could have been seriously entertained by grave and learned dignitaries, when the proofs were so abundant to the contrary. Yet at a later day, we find the Jesuit Fathers, P. P. Le Seur and Jacques declaring in the preface of their edition of Newton's Principia:

"Newton in this third book, has assumed the hypothesis of the earth's motion. The author's propositions are not to be explained but by making the same hypothesis also. Hence we are obliged to proceed under a feigned character; but in other respects, we profess ourselves obsequious to the decrees of the Popes made against the motion of the earth."

Such was the strong hold which ignorance had upon the minds of men, that like Sizzi, who refused to look through Galileo's telescope for fear he might be obliged to acknowledge the actual existence of Jupiter's satellites, they would not receive the truth when it was absolutely forced upon them. Even in the present enlightened state of the world, there are many who object to the science of Geology, because some of its teachings, they imagine, are contrary to the word of God.

Religion and Philosophy can never conflict, if both are based upon the Truth. We may be well assured, that the rapid advancement of science and art, will, so far from being injurious to the cause of Religion, tend but to illustrate, and exhibit, in clearer characters, the wisdom and goodness of the Creator. Nothing can be more unwise, or of greater injury to the cause of Religion, than the foolish opposition which is sometimes made to the recent developments, if they may be so termed, of natural science. Religion points us to another sphere of action; it opens before us another world; and bids us aim for higher and nobler ends than we strive for here. The questions, whether the Heavens are eternal, or our own earth a million, or six thousand years old, are of little moment compared with the question of the immortality of the soul. Science elucidates the former, Religion the latter. Since, then, their aim is so very different, and since we believe both to be based upon Truth, and therefore immutable, why perplex ourselves with questions which can never be answered?

To the Geologist, the proof is abundant, that the present globe has had a being, and been inhabited by wonderful animals and plants, myriads of years past. To the Astronomer, the proof is equally conclusive, that the Heavens are infinite, and eternal, that our system will, at least so far as natural causes are operating, continue for ever, unchanged, and unchangeable. To the Christian, the proof is equally strong, perhaps stronger, that the word of revelation is what it professes, the message of God, teaching what Science could never learn us, but not conflicting with it.

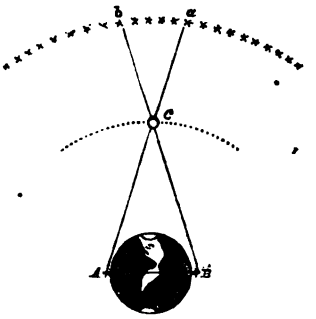
CHAPTER III.

Parallax.

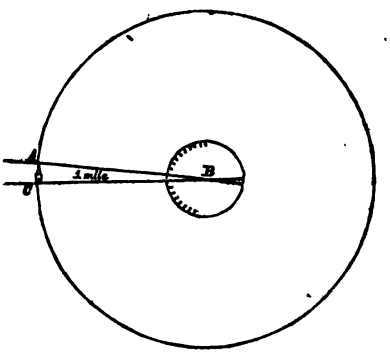
"The broad circumference
Hung on his shoulders like the moon, whose orb
Through optic glass the Tuscan artist views,
At evening, from the top of Fesole'
Or in Valdarno, to descry new lands,
Rivers or mountains, in her spotty globe." — *Milton.*

We have now shown that our earth is revolving around the sun, which is the grand central luminary, and that within its orbit are the orbits of Venus and Mercury, while exterior are the orbits of Mars, Jupiter, and Saturn. We have learned to look upon these bodies as orbs, or balls like our own earth, and suppose them to revolve like our earth upon an axis. We now desire to know something of their distance from us, and the actual velocity with which both we and they are moving. The diameter of our earth we have assumed at 8000 miles, or equal lengths, we can, from knowing this, ascertain the distance of the moon from the earth, and of the earth from the sun. Every one is familiar with the fact, that every change of position of a spectator, causes an apparent change of place in the object viewed. Thus, if while in a certain position, we observe a particular house to be in the range, or same line with a distant tree, then upon changing our position, the house will no longer be in a line with the tree, but will appear to have moved in the contrary direction. This apparent change of place of the object, due to a real change of place in the observer, is called parallax, and by its means, we can determine the distances of the heavenly bodies. Thus, supposing spectators on opposite portions of the earth's surface, as at A and B, to view the moon or a planet, at *c*, the observer at A, will see the object *c*, apparently at *a*, while the observer at B will perceive it at the same time at *b*. Here is an apparent change of

place, viz: from *a* to *b*, due to a real change in the position of



the spectator. This change, enables us to ascertain the distance of the object with much precision, for supposing A and B joined by a line, we have a triangle A B C, in which one side A B, is known, and all three angles — for the observers at A and B determine with some graduated instruments, the inclinations of the lines A *c* and B *c* to the line A B. We can illustrate the method by which the distance of an object is ascertained by means of graduated instruments thus:

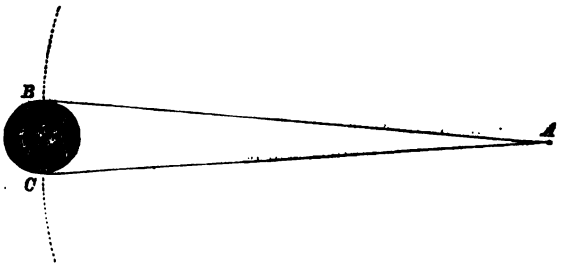


Suppose a spectator at B, to observe by means of a graduated

circle, the number of degrees subtended by a distant object, as a church, at A C, and let this angle be two degrees; we have here a triangle A B C, and knowing its angles, and any one side, we can determine the other sides. Suppose we know the side B C, or the distance of the Church, to be 1 mile, we can ascertain the height A C thus: Twice B C, or 2 miles, will be the diameter of a circle whose centre is the eye of the spectator, and whose radius, the distance of the Church. Three times this (nearly), or 6 miles, will be the whole circumference, and six miles divided by 360 will give the length of one degree, and twice this, since the angle A B C is 2 degrees, will give the height A C. Allowing 5000 feet to the mile, 6 miles would be 30,000 feet, and this divided by 360, gives $83\frac{1}{3}$ feet for the length of one degree, consequently 2 degrees are $166\frac{2}{3}$ feet, which is the height required. Now in any triangle whatever, we can determine the length of all its sides, provided the length of one side is given and also the angles. We do not mean to be understood that this is the actual process employed by astronomers to determine the distance of the moon, and other heavenly bodies, but simply introduce it as an explanation of the principle.

By means of parallax, the distance from the moon to the earth has been ascertained to be 60 semi-diameters of the latter, and the distance of the earth from the sun has been determined to be 95,000,000 of miles. When we reflect upon this vast distance, the absurdity of that system which denied to the earth a revolution on its axis, once in 24 hours, is strikingly apparent. We could not conceive of the amazing velocity with which the sun must move, at the immense distance which it is situated from the earth, if it was obliged to travel once around in 24 hours. It would require a rate of about 24,000,000 miles per hour, or 400,000 miles in one minute, and 6,666 miles each tick of the clock. Such velocity is absolutely incredible, and this would be to save our little globe from turning on its axis at the rate of 1000 miles an hour, or about 17 miles in one minute.—When the distance of any of the heavenly bodies becomes known, its actual diameter in miles can be easily ascertained. It is no more difficult to obtain the diameter of the

moon, when her distance from the earth is known, than to determine the height of a church steeple when we know how far it is from the observer. We here represent the moon and a part of



its orbit, the earth being supposed to be at A. The distance A B or A C, is 240,000 miles, and the angle B A C, which is observed with a graduated circle, is about 30 minutes, or half a degree. Proceeding as in the case of the Church, twice A C is 480,000 miles, and three times this is 1,444,000 miles which is the circumference of a circle whose centre is the centre of the earth, and whose radius, or half diameter, is the distance of the moon. This circumference divided by 360, gives 4000 miles for the length of one degree, and half this is 2000 miles the length of half a degree, which is the diameter of the moon. The actual diameter of the moon is 2140 miles, for the angle B A C is nearly 31 minutes, or a little over half a degree.

In precisely the same manner the diameter of the sun is ascertained to be 880,000 miles. Hence we learn, that if a spectator at the sun, should look towards the earth, it would appear only the one hundredth the diameter which the sun appears to us, or not larger than a very small star. How absurd then is the idea that the sun revolves around the earth.—We now have a just conception of the solar system, and have learned to look upon the sun as the central body, around which the planets revolve in order, our earth being one of the smallest. Far beyond it, other magnificent orbs are moving silently in the depths of space, peopled with myriads of intelligent beings. Very far beyond the boundary of our own system, we believe there are others more beautiful, and

that every star which adorns the heavens, and upon which we turn such unheeding eyes, is a sun, giving light, and warmth, and happiness to its own attendant planets. Nay, more than this, we believe that all those countless myriads of stars which the telescope reveals, twinkling from distances so far, that if blotted from existence, their light would continue a thousand years, so long it would take to travel thence to us, are all centres of systems, around which, worlds peopled with intelligences of the highest order, are revolving, and yet, we have obtained but a faint idea of the immensity of Creation. Where is the central throne from which all power emanates? The throne of the Eternal. Imagination fails. Reason shrinks back abashed, but Faith, with more than telescopic eye, pierces to that centre, and sometimes catches a gleam, a faint ray of the brightness of its glory. What wonder that astronomy should be called the noblest science, since it affords scope for the highest order of intellect, and presents truths unequalled for their grandeur and sublimity. Unconsciously we are moving on, life and death is every where around us, but the heavens seem unchangeable, the type of eternity. We are unwilling to believe that the principle within us, whatever it may be called, soul, spirit, or reason, which is thus capable of comprehending sublime truths, perishes, and becomes inanimate, like the dead flowers, and withered leaves. We feel an ardent aspiration after higher and purer knowledge, and cannot doubt that such longings will one day be gratified.

These may be called "flights of the imagination," but we would do well to remember, that there *are* things, which are as far beyond the imagination to conceive, and which are more strange than this, yet of whose reality we cannot doubt. Such is the progression of light, and of electricity. The eye cannot follow them, nor the imagination, as they rush on, with a speed of 200,000 miles in one second! And, quicker than this is the transmission of that mysterious influence, called gravitation, which acts with all-controlling force, through distances, utterly inconceivable to the human mind, causing the immense masses of the planetary orbs to rise and fall like bubbles on the ocean wave. Shall we then call all these flights of the imagination, or mere fancy, and with

those doubting men of old, deny the reality of everything, even our own existence?

We give above a representation of the earth, as it would probably appear to a spectator removed to the distance of the moon. The same hemisphere of the moon is always turned towards the earth, this is caused by a revolution on its axis in the same time that it revolves around the earth. Consequently, a spectator on the moon, would always behold the earth as a stationary body in the heavens, as we should behold the sun, if the earth turned on its axis but once in 365 days. The apparent size of the earth, seen from the moon, would be a globe of about four times the diameter of the moon. In the imaginary view we have given, the great Indian Ocean is directly in front, the Pacific at the right, and the Atlantic at the left. The large inland seas are shown; also, Europe, Africa, Asia, and New Holland; and around its north pole are fields of ice, and cloudy patches are over the whole surface. Such a vast globe, suspended apparently in the heavens, and revolving on its axis with a motion easily perceptible, must be a magnificent spectacle, and if the moon is really inhabited, well worth a journey round half its surface to behold.

CHAPTER IV.

Time.

"The last white grain
Fell through, and with the tremulous hand of age
The old astrologer reversed the glass;
And, as the voiceless monitor went on,
Wasting and wasting with the precious hour,
He looked upon it with a moving lip,
And, starting, turned his gaze upon the heavens,
Cursing the clouds impatiently." — *Willis.*

We have now determined the relative situation of our earth with regard to the heavenly bodies, and its size compared with them, and we are prepared to investigate the causes of some of the changes which we witness upon its surface. Previous to this, we will devote a few chapters to Time and the Calendar, for the familiar expression of a day, or an hour, or a year, seldom conveys to the mind the exact meaning which belongs to those terms. We may consider time to be a definite portion, that is, a portion which can be measured, of indefinite duration, or, as Young poetically expresses it:

"From old Eternity's mysterious orb,
Was Time cut off, and cast beneath the skies."

Time was personified by the Ancients, under the figure of an old man with scythe and hour-glass, and a single tuft of hair on the forehead. The scythe was emblematic of that all-powerful influence which cuts down every thing as it sweeps past. Man, and his works, perish, and crumble before it, as the grain falls before the mower's scythe. Nor is the emblem unappropriate. The keen edge, while it sweeps through the field of ripe grain, suddenly laying low the proud stalk, cuts down many a flower, and tender stem. The hour-glass, held in the outstretched hand, portrayed the passing moment, and the sand, in its ceaseless flow, marked the ebbing of the current of life. We cannot

refrain from quoting a beautiful little poem, from "Hone's Every Day Book," entitled

INSCRIPTION,

FOR MY DAUGHTERS' HOUR-GLASS.

Mark the golden grains that pass,
Brightly thro' this channell'd glass,
Measuring by their ceaseless fall,
Heaven's most precious gift to all!
Busy, till its sands be done,
See the shining current run;
But, th' allotted numbers shed,
Another hour of life hath fled!
Its task perform'd, its travail past,
Like mortal man, it rests at last!—
Yet let some hand invert its frame,
And all its powers return the same,
Whilst any golden grains remain,
'Twill work its little hour again,—
But who shall turn the glass for man,
When all his golden grains have ran?
Who shall collect his scattered sand,
Dispersed by Time's unsparing hand?
Never can one grain be found,
Howe'er we anxious search around!

Then, daughters since this truth is plain,
That Time once gone, ne'er comes again,—
Improv'd bid every moment pass—
See how the sand rolls down your glass!"

The forelock was also emblematical, indicating that if we would improve the time, we must take it by the forelock, and that time once passed left no hold by which it could be reclaimed. Such was the beautiful emblem of time devised by the ancients, and which we still retain.

The diurnal revolution of the earth, or rather, as it was once believed, the revolution of the heavens around the earth, was observed at a very early day to be performed with the utmost regularity. The return of night, and approach of day, the duration of the night and day, are the first great natural phenomena which engage attention, and we may suppose, therefore, that the apparent revolution of the stars around the earth was at a very early period, employed to determine equal intervals of time. Sun-dials were undoubtedly the earliest means employed

to mark the passage of time, and are in common use even at the present day. Every country tavern is furnished with its meridian or noon-line, which oftentimes is nothing more than a scratch or mark in the floor, and the gnomon, or shadow-stick, is the side of a window or door. In our younger days, we have watched with far more interest, the shadow approach the humble line drawn on the floor of a tinker's shop, than in more mature years the steady passage of a star over the wires of a transit telescope. And we have not forgotten those days of sun-dial memory, when we were, unconsciously, children playing with time. We find allusions to the dial in the Old Testament. The dial of Ahaz, which was, undoubtedly, a large public edifice. Such was the dial constructed by Dionysius, and such the dial used by the Chinese, and in India. Sun-dials were liable to many objections; they could only be used when the sun was shining, and consequently at night, or in cloudy weather they were worthless. The Clepsydræ, or water-clock, was therefore invented at an early date. It is said that they were found among the ancient Britons, at the time of the invasion by Julius Cæsar.

The first water-clocks were made of long cylindrical vessels, with a small perforation at the bottom. These being filled with water, marked the passage of time by the descent of the fluid column. Various ornamental contrivances were subsequently introduced, but they were all dependent upon the same principle.

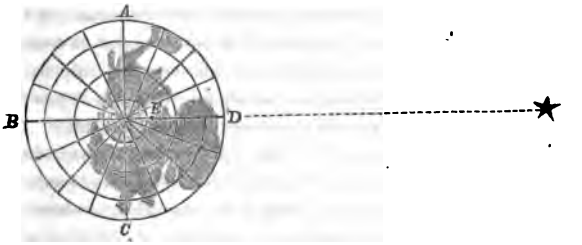
We will imagine one of the early philosophers, with his water-clock, starting the stream when some well known star was occulted, or hidden by a distant object, the tube being long enough to continue the stream until the next night. As the heavens move on, we find him watching the descent of the liquid, and at the approach of the succeeding evening, when the same star is again occulted by the same object, he marks the level of the liquid in his tube, and selecting another star, for the first has gone out of sight, he fills the tube, and at the given signal, when the star passes behind the hill, or other occulting object, he permits the water to flow. On the succeeding evening, as this star is again hidden, he observes the fluid, and finds it at precisely the same level as before, and thus arrives at the conclusion that the stars

all revolve around the earth in the same time, or, more philosophically speaking, he learns that the earth turns uniformly on its axis—performing each revolution in exactly the same interval of time. The space thus obtained on the clepsydra, for a revolution of the heavens, we may imagine him dividing into portions that will mark the subdivisions of the day. These divisions would not all be equal, but decrease in length as the height of the fluid column decreased. His instrument thus adjusted to measure the flight of time, we may suppose him to observe the exact instant of sunset, and after an interval of a day, again making the same observation. He would find upon careful observation that this interval was longer than the interval required for a star to revolve around the earth, by about 4 minutes, if his instrument would detect so small a quantity. In other words, he would find that the sun was apparently moving backward in the heavens. And now, he is, perhaps, for a moment puzzled which measure of time to adopt, that of the stars, or of the sun. Convenience points out the latter, and consequently astronomers regulate their time measurers to divide the *solar day* into 24 hours; the other is called the *siderial day*, and is about four minutes shorter.

For a long time, even after Copernicus and Galileo had established the fact of a rotation of the earth on its axis, there were no means of measuring intervals of time more correctly than by the water-clock. It is true, that instruments made of wheels, and moved by weights, were, in Galileo's time, in use, but as they were without any regulators, the time was too inaccurately measured to be of any service. The discoveries which were being made by Tycho Brahe, and Kepler, demanded some more accurate method of registering the time. It is related that Galileo, observing the swinging of a suspended lamp, in a Church at Pisa, and noticing that the vibrations, whether long or short, were performed in equal times, conceived the idea of adapting such a contrivance, now called a pendulum, to measure intervals of time. His apparatus was rude enough, and it was necessary to employ a boy to occasionally give the pendulum a slight push when it was near resting. It does not appear, at first

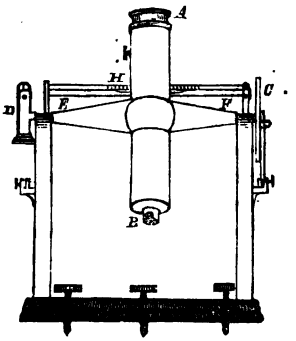
thought, that long and short vibrations will be performed in the same time—yet this is true, at least when the pendulum is quite long, and the arcs over which it swings are of moderate lengths. Huygens conceived the idea of applying the pendulum to the clock, as a regulator, and succeeded in accomplishing this, and thus gave to the world an accurate measurer of time. The clock thus perfected, became so accurate, that it was necessary to contrive some more accurate means to regulate it. Hitherto, the successive occultations of some star, observed without the aid of a telescope, had been sufficient, and the time of noon, or 12 o'clock, was obtained by sun-dials, and other means, with sufficient accuracy, for the instruments hitherto employed.

Any occurrence, which takes place at regular intervals, may be adopted as a regulator of time, but the revolution of the earth on its axis is by far the most accurate. For certain reasons, which will be given presently, the sun is apparently subject to such irregularities, that the solar days, or exact interval, from the time the sun is on the meridian, until his return to it again at the successive revolution, are of unequal lengths. In other words, the solar day is variable. Now the real revolution of the earth on its axis, is the time in which any given meridian, or situation on the earth, moves from a particular star, back to that star again. Thus :



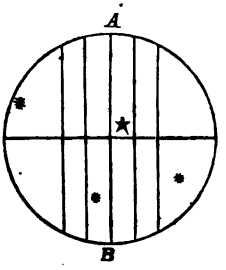
Let A, B, C, D, be the earth, its north pole N, being towards us, and suppose it revolving in the order of the letters. Let N D be the meridian, or north and south line passing through some particular spot, Greenwich, for example, shown at E, and let the star S, be upon the meridian, that is, if this line was extended to the heavens, or, more properly, a plane passing through this

line, suppose the star to be upon it. As the earth turns on its axis, the star is left behind, and after a complete revolution, the meridian again arrives to it, this interval is called a *sidereal day*, or day as determined by the stars, and to ascertain this day, or its length, we must have some means of determining with the utmost exactness when the star is on the meridian. This is accomplished by means of the transit instrument, invented by Huygens, and shown in the engraving below.



The ordinary transit instrument consists of a telescope, A B, of any convenient length, fixed firmly at right angles to a conical hollow axis, E F, the extremities of this axis are truly turned, and rest in two angular bearings which are called Y's, since they are not unlike this letter, the instrument can be lifted out of these bearings, and reversed, so that the ends E and F may change places. The end of the axis F, is furnished with a small graduated circle C, for the purpose of reading the elevation, or altitude of the body observed, and at D, is a small lamp, the light of which shining into the hollow arm E, is reflected by a reflector inside the tube, down to the eye. The object of this illumination is to make a system of fine lines, ustually raw silk, or spiders-web, visible at night, at the same time with the star. In looking into the transit telescope, five of these lines are usually seen, shown in the engraving. A B is, by means we cannot now describe, located

as exactly in the meridian as possible. It will be seen that when the axis of the transit telescope, E F, is placed due east and west, and also made perfectly horizontal by means of the spirit level H, the telescope A B, will move in the meridian, *i. e.*, it will, if



directed to the heavens, mark the exact situation of the meridian, at the time, of the particular place where the instrument is located. We are thus furnished with the means of determining, with the greatest exactness, the precise time of a siderial revolution of the earth, and as the apparent time of noon, or twelve o'clock, is precisely the instant when the sun's centre is on the meridian, we are also enabled to determine, with considerable precision, the local time, or clock time at the place,

The transit instrument and the astronomical clock, are the two chief instruments of the observatory, and by their means, the positions of celestial objects can be ascertained with the utmost nicety. It would be out of place for us to describe more minutely these invaluable aids to the astronomer, and we pass to consider in the next chapter, the "Calendar," or the division of the year into months, weeks, and days, and at the same time we shall give an historical sketch of its gradual progress to the present state of perfection.

It is a difficult thing to comprehend fully, or even partially, the relative dimensions, situation, and movement of our globe. We are so accustomed to look around us and behold the solid foundations of the earth, to see plains and oceans, extending as far as the eye can reach, and man is so small, when compared with the

immensity of creation around him, that we are wont to look upon the hills as everlasting; and the ground whereon we tread, and in the utmost confidence build houses, and proud works of art, as unchangeable. We are so accustomed to behold the grand luminary which gives light and warmth to the world, and cheers myriads with its bright rays, rising and marking out the length of a day; we are so accustomed to plan ahead, and to contrive for years yet to come, as though there was no possibility of a change; we are so accustomed to behold the fair orb of night, as she illumines a quiet and sleeping earth, and so wont to gaze upon the ever-twinkling and bright stars, that we long ago have ceased to think of our earth as a minute orb, smaller by far than many of those upon which we turn such careless eyes now. We rarely, if ever, imagine that its present surface was once the bed of a vast ocean; that its present crust has been caused to heave and swell like a sheet spread out upon the waves, uplifted by internal fires, until the strained surface has cracked open, and the flames, and molten rock found egress. Careless from a thousand causes, we deem ourselves, like the conceited wise men of old, as the only important beings of the universe, and our habitation, as eternal, and unchangeable. It is the peculiar province of Astronomy and Geology, to free the mind from such superstitions, and to elevate and ennoble it by loftier contemplations. The younger Herschel, has truly remarked, "Geology, in the magnitude and sublimity of the objects of which it treats, undoubtedly ranks next to Astronomy in the scale of the sciences."

We have, in the present volume, associated the two, as was necessary in giving such a sketch of the earth as was planned, and shall strive to interest as well as instruct the reader. — Of one thing we are most certainly convinced, and that is, there is not a more interesting subject, to which we may devote our attention.

CHAPTER V.

The Calendar.

"Change of days
To us is sensible; and each revolve
Of the recording sun conducts us on
Further in life, and nearer to our goal."—*Kirk White.*

THE revolution of the earth on its axis, being adopted as the standard of measure, it was natural that the number of days to the year should be a subject of early investigation. We have already alluded to the helical rising of the stars, and it is apparent that upon ascertaining the distance of the sun from any particular star, and after a certain interval, determining when his distance from the same star, is the same as before, the early astronomers could determine the length of the year, or time occupied by the sun in his apparent revolution around the earth. As it was difficult to observe any stars at the same time with the sun, its place in the heavens, or position in the ecliptic, was determined by measuring its distance from Venus, and then the distance of Venus from some known star. Or, we may imagine the time of sunset to be carefully observed, and afterwards the time of setting of some particular star, then, upon making due allowance for the time elapsed, the sun's position among the stars could be ascertained. The rising and setting of certain stars, or constellations, was early adopted as the precursor of the return of certain seasons of the year. We find continual allusions to this among the early poets, and even in the Book of Job, we have, "Canst thou bind the sweet influence of the Pleiades, or loose the bands of Orion? The Pleiades were also called Vergiliæ, *i. e.*, daughters of the spring. The Egyptians watched in like manner the rising of the dog star, which gave notice of the approaching season of inundation by the Nile. The length of the year was soon

ascertained to be about 365 days; and as the moon, apparently, made near 12 revolutions around the earth in that time the year was subdivided into 12 months, which, in reference to the phases of the moon, were again subdivided into weeks, of seven days each. — The time occupied by the sun in the departure from any particular meridian, until its return to that meridian again, is called a *Solar day*, and a similar revolution, a star being the object, is called a *Siderial* day. We have already shown that the Solar day was longer than the Siderial day, on account of the apparent backward motion of the sun among the stars; but it is obvious, that the Sidenial day, is the true measure of the time of revolution of the earth on its axis. Now if the earth made an exact number of revolutions on its axis, during the time in which it moves from a particular part of the heavens, back to that particular position again, it is evident we would have an exact number of siderial days to a year.

It is found, however, that the siderial year does not consist of an exact number of days, but contains, also, a fractional part of a day. When a long interval of time elapses between different observations, so that the earth makes a great number of revolutions around the sun, the length of the year may be very correctly ascertained. Thus — On the 1st day of April, 1669, at 0h. 3m. 47s., mean solar time, (which we shall explain presently,) Picard observed the distance of the sun from the star Procyon, measured on a parallel of latitude, to be 98° 59′ 36″. In 1745, which was 76 years after, La Caille observed the sun, to determine exactly the time when his difference of longitude should be the same from the star, as in Picard's observation. Now the day of the month in which La Caille observed, had been reckoned on from Picard's time, just as if the year had consisted of exactly 365 days, except every leap year, when a day had been added, for a reason that will appear presently. It was not until April 2d, at 11h. 10m. 45s., mean solar time, that the difference of longitude was the same as when Picard observed. Now here it was obvious that the earth had in reality, made just exactly 76 revolutions. The number of days however, was as follows, viz: 58 years, of 365 days each, and 18 leap years, of 366 days each,

and 1d. 11h. 6m. 58s. more, or in all, 27759d. 11h. 6m. 58s., which being divided by 76, gives 365d. 6h. 8m. 47s. for the length of the Siderial year. More recent and exact observations give 365d. 6h. 9 m. 11s.

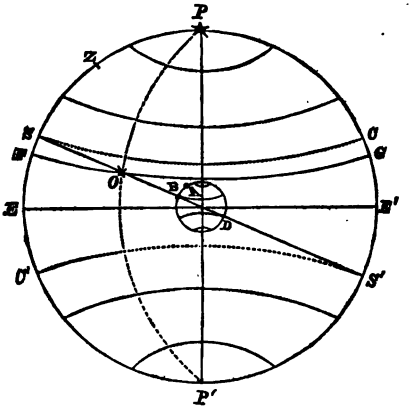
There are various kinds of years. First, the *Siderial year*, or the time which it takes the earth to perform exactly one revolution around the sun. This year it is not expedient to use, for the seasons being dependant on the position of the earth with regard to the sun, it is more convenient to have for the length of a year, the time from the commencement of spring to the commencement of spring again, and this is a period which, for a reason we will soon explain, is shorter than a siderial year. This year is called a *Tropical* or *Equinoctial year*. Again, inasmuch as this year does not consist of an exact number of days, and as it would be excessively inconvenient to have a year begin at any other time except the commencement of a day, we have the *Civil year*, which consists of exactly 365 days, and every fourth year, of 366. — We have already given the length of the Siderial year, which is the time of a true revolution of the earth in its orbit, but the length of the equinoctial year, or year from beginning of spring, to spring again, is shorter than this. It is obvious that the equinoctial year is the one which most intimately concerns us, all agricultural, and other operations, being entirely dependant upon the seasons.

When we explain, in the next chapter, the cause of the seasons, we shall show why this year, must be shorter than the Siderial year. Meantime we may suppose one of the early philosophers detecting it in this manner. The path of the sun in the heavens being ascertained, it was soon observed that it was inclined at a certain angle, with the apparent diurnal paths of the stars. Thus, if we observe a certain star to-night, (mid-summer,) which rises due east, and watch its diurnal path, or the line which it traces in its apparent motion over the heavens, we will find it a part of a circle, whose centre is the pole of the heavens, near which the pole star is situated, and the star will set due west: at a certain point midway between east and west, it will reach its highest altitude, after which it will begin to set, this highest altitude is

when it is in the meridian, or mid-heaven, and the meridian of a place, is a plane, or direction, which passes through the spectator, and the north and south point. If we observe another star which rises 10° south of east, we will find it arriving to the meridian something more than 10° lower down than the other star, according to our latitude. If we were at the equator, it would be just 10°. This star would set 10° south of west, and so of any stars whatever, they would all apparently describe diurnal circles, or parts of such circles, all having the pole of the heavens for their grand centre. Now at the time of the summer solstice, or mid-summer, 21st of June, the sun rises directly east, and sets due west, describing apparently a diurnal circle in the heavens, after a few days, however, he will rise a little south of east, and set a little south of west, and in a few days more he will rise still farther south of east, and set so much south of west, until at the time of the winter solstice, or mid-winter, he will, in our northern latitude, rise very far towards the south, and come to the meridian very low down, and set at as great a distance south of the west point, as he arose south of the east. Now, if the backward motion of the sun in the heavens, had been performed in a diurnal circle, he would rise later and later each day, but always just at the same distance from the east. Hence we infer, that this backward motion of the sun, is not in a diurnal circle but inclined to it. This is the case, the ecliptic, or sun's apparent path, instead of corresponding with the equator, or with any particular diurnal circle parallel to the equator, cuts them all at a certain angle, which angle is called the inclination of the ecliptic. In order to make this part of our subject clear, we must have reference to a diagram.

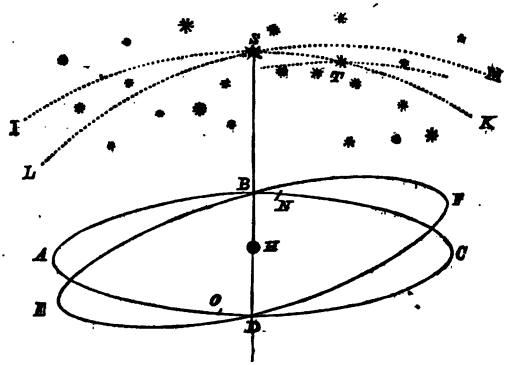
Let P P′, be the poles of the celestial vault or concave, having the earth A, within it, its poles being in the line P P′. As the earth turns around on its axis, let its equator reach the heavens, marking E E′ as the celestial equator. Through a point B, at the distance of 23½° from the equator, suppose a line B S, which also passes through the centre of the earth, to reach the sky at S. As the earth turns around, this line, B S, will mark out a circle in the heavens, C S, called, for a reason which will soon be given,

the tropic of Cancer. A similar line D S, which passes through



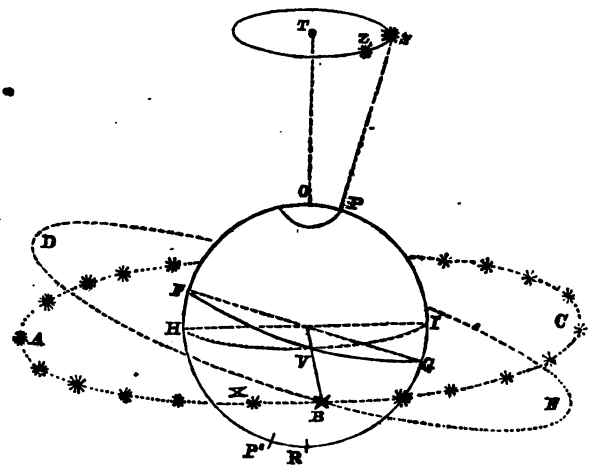
the centre of the earth, and a point $23\frac{1}{2}°$ south of the equator, will trace out the circle C′ S′, called the tropic of Capricorn. The circle P E′ P′ E, will represent a meridian, or a great circle which passes through the poles and the centre of the earth. Let S S′, be a great circle, (of course seen edgewise in the diagram) this will represent the ecliptic which is inclined $23\frac{1}{2}°$ to the equator E E′. When the sun is at S in the ecliptic, his apparent diurnal path in the heavens, as the earth turns around, will be the circle C S; and to a spectator at B, the sun would be directly vertical, or overhead, at noon. If we suppose a little circle marked on the earth, corresponding with C S, we can readily perceive, that, as the sun is fixed, while the earth turns around, all those places upon the earth which lie in this circle, will have the sun vertical at noon. But a spectator at A, nearer the north pole of the earth, would have his Zenith, or highest point of the heavens, as at Z, hence the sun would come to the meridian below the Zenith. This is the case at all places north of the tropic of Cancer, or south of the tropic of Capricorn. Suppose now the sun to have moved in his orbit from S to O, he would then appear to rise at the same time with the star O, and describe the diurnal circle F G in the heavens, parallel to the equator, arriving at the meridian

considerably lower than in the first case. The dotted line P O P′ will here represent the meridian, which, it must be remembered, is not a fixed direction in space, but simply a plane, extending from the earth to the heavens, and passing through the spectator, wherever he may be, and the poles of the earth. When the sun, after moving through one fourth of his orbit, arrives at the point where the equator and ecliptic cross each other, and which is called the equinoctial point, the days and nights are equal all over the world, and the sun is vertical at noon, at the equator. His apparent diurnal circle will now be the equator E E′. The sun, still moving on in its orbit, finally arrives at S′ its greatest southern limit, describing the diurnal circle S′ C′ at the time of the winter solstice; after which it again moves northward, rising higher, and higher, each day, until after a tropical year, it arrives at the point S, where we commenced. Now if the points S and S′, were fixed points in the heavens, the length of a tropical, or equinoctial year, would be the same as the length of a siderial year, for the equinoctial points are fixed with regard to the tropical points. It is, for many reasons, more convenient to reckon this year from equinox to equinox, and hence this is generally termed the equinoctial year.



Let A B C D, represent the sun's path, inclined 23° 28′ to the equator E D F B, and suppose B, the position of the vernal equi-

nox, and let the apparent positions of the ecliptic and the equator, or rather portions of them, be represented by the dotted lines, and suppose some star S, to lie directly in the equinoctial point, or node, as seen from the earth at H. Suppose the sun, commencing from the point B, or S, to move around in the direction B A D C, it is evident, that if the crossing point still corresponded with the star S, or remained unchanged, the sun would arrive at B, or S, after an interval equal to a siderial year. But this is not the case, the plane of the equator E D F B, is not fixed, but while the sun is performing his journey, it moves slowly backward on the ecliptic contrary to the apparent yearly motion of the sun in the heavens, so that, in about the time of a year, the crossing points are at N and O, and in the heavens the position of the vernal equinox will appear to have shifted, contrary to the order of the signs, from S to T; hence, as the sun arrives at T before it can come to S, the equinoctial year is shorter than the siderial year. This shifting of the nodes is called the *Precession of the Equinoxes*, because the equinox seems to go forward to meet the sun, and thus *precedes* the complete revolution of the sun in the ecliptic. Now this



change of place, in the position of the equinox, we infer very

readily, must be caused by a motion of our earth, for it will be noticed, that the inclination of the ecliptic to the equator remains unchanged.

Let A B C, represent the ecliptic, and D B E, the celestial equator, intersecting each other in two opposite points, one of which is shown at B. Let P P′ be the poles of the earth, 90° distant from the equator F V G, in every direction, and let the star S, in the direction P′ P, be the pole of the heavens, every where 90° distant from the celestial equator, D B E, let the point T, be the pole of the ecliptic A B C. We must be careful and not consider the lines F G, H I, marked on the earth as equator and ecliptic, to be fixed, because this would cause the nodes, or equinoctial points, to revolve, apparently, once in a day, through the heavens, but we may suppose them hoops or bands, stationary, while the earth turns around in them. For a moment suppose the diurnal revolution of the earth to be stopped, and let the position of the intersections of the planes of the celestial ecliptic and equator, meet on the earth at V, and let the poles, of the ecliptic H V I thus marked on the earth, be O and R, a spectator at the centre of the earth, would locate the equinoctial point among the stars at B. If, now, the earth should be turned a little, not on its diurnal or equatorial axis P P′, but on its ecliptical axis O R, in the direction of the letters C B A, the equinox would appear to shift in the heavens to the star X, and the pole of the heavens S, would appear to have moved partly around the pole of the ecliptic S, and be at Z. This is the fact, whilst the earth is moving around the sun, and all the time turning daily on its *equatorial* axis, it is making a slow backward revolution around its *ecliptical* axis, and as the stars are fixed, the equinoctial point continually retrogrades along the ecliptic, thus causing the pole of the heavens continually to shift its place, revolving in a circle whose radius is T S, which is the angular inclination of the axis P P′ to the axis O R, or of the plane of the ecliptic, to the plane of the equator. The early astronomers, located the places of the equinoxes in the heavens, and gave the name *Aries* to the constellation where the vernal, or spring equinox, was located, and the name *Libra* to the constellation where the autumnal equinox was located. Since that

time, the equinoctial point has retrograded 30°, or one sign, the whole circle, 360°, being divided into 12 signs of 30° each; consequently, the vernal equinox is now in what was then the last constellation, *Pisces*, for the stars have not changed places, only the intersecting point. Astronomers, however, have agreed to call the point where the vernal equinox is situated, the first point of Aries, forever, whatever may be the constellation where this point is located, hence the *sign* Aries, is now in the *constellation* Pisces, the *sign* Pisces, in the *constellation Aquarius*, &c. The annual amount of precession is small, being but 50.1″ in a year, hence the time occupied to make a complete revolution, will be 25,868 years. However, small as it is, it is quite palpable in the course of a century, and has been of signal aid in Chronology as we shall show in our chapter upon that subject. As the place of equinox goes forward each year, to meet the sun, 50.1 seconds of space, it is evident the tropical or equinoctial year will be as much shorter than the siderial year, as it takes the sun to describe this small space, which is 20m 20s, nearly, hence the length of the equinoctial year is 365d, 5h, 48m, 51.6s, and this is the year which most intimately concerns us. In ancient times, the days of the summer and winter solstice were determined by means of the shadow of a gnomon, or upright post, as the sun rose higher and higher each day, at noon, the shadow became shorter and shorter, until, having reached its limit, it began to lengthen, this was the day of the summer solstice. The day of the winter solstice, was the time of the longest shadow. When we look back, and think of the ancient philosophers, with their shadow-sticks, and rude dials, and see them trying, with these rough means, to measure the distances of the heavenly bodies, and the size of the earth, we may wonder that they ever approximated as near as they did. In no Science has the advancement of general learning and civilization been more apparent, than in Astronomy. Tables of the positions of the sun, moon and planets, in the heavens, are now given for many years to come, with such accuracy, that the unassisted eye cannot detect even their greatest errors, and in some cases, the positions are given with more accuracy than even could be obtained from observation itself.

The tropical, or equinoctial, or mean solar year, for these different names all mean the same, is, as we have just shown, about 365¼ days long. Now if this year was to begin upon the first day of January, at 0h, 0m, 0s, the next year must begin January 1st, at 5h, 48m, 51.6s, or about a quarter of a day later. This would be excessively inconvenient, hence it was determined to have the civil year consist of 365 days exactly, and this, for a long period, was the case, but the consequences, after awhile, became very apparent. The vernal equinox, which once was at the commencement of the spring months, gradually began to go back, until the calendar was involved in great confusion. This was especially the case with the Roman Calendar, in which the year was reckoned 12 revolutions of the moon, or 354 days, and Julius Cæsar, with the aid of Sosigenes, an astronomer of Alexandria, attempted a reformation. The beginning of the year had formerly been placed in March, by Romulus, in honor of his patron, Mars. Cæsar determined to commence the year the 1st of January, at the time of the winter solstice. This seems the most natural time, for now, the sun, having reached his greatest southern declination, begins to return, bringing back the spring and summer. Cæsar chose, likewise, to have, for the first year of the new calendar, a year when a new moon happened near the time of the winter solstice. This occurred in the second year of his dictatorship, and the 707th from the founding of Rome, when there was a new moon on the 6th of January. This, accordingly, was made the beginning of a new year, and in order to make the year commence at this period, it was necessary to keep the old year dragging on 90 days, or to consist of 444 days. All these days were unprovided with solemnities, hence the year preceding the commencement of Cæsar's calendar is called the *year of confusion*. To prevent the recurrence of error, which was what he had most in view, and keep the *civil* and astronomical years together, he determined to add, each fourth year, a day to the calendar, because the solar year being, as was then supposed, 365¼ days long, this ¼, would, in four years, amount to a day, and could then be added. It was true, the second year would begin 6 hours too soon, the third would begin 12 hours too soon, and the fourth 18 hours too soon, but the

commencement of the fifth would correspond with the fifth astronomical year. In the month of February, the lustrations, and other piaculums to the infernal deities, ceased on the 23d day, and the worship of the celestial deities commenced on the 24th. Cæsar chose, therefore, to insert this intercalary day between the 23d and 24th days of February. The Romans did not number their days of the month as we do now, *i. e.* 1st, 2d, 3d, &c., but they called the first day the *Calends*, from which our word calendar is derived, thus the 1st day of March was called the Calends of March, the 28th day of February was called the *pridie Calendas Martias*, the day before the calends of March, the 27th was called the third day of the Calends of March, and the 24th was the *sextus*, or sixth day, of the Calends of March, and as Cæsar's intercalary day was added just after this day, it was called *bissextile*, or double sixth day, and the year in which it was added, received, and still bears the name, *bissextile*. Many years after, when Christianity became the religion of the Roman Empire, Dionysius Exiguus, a French Monk, after much research, came to the conclusion that the 25th day of December, of the 45th year of Cæsar's era, was the time of the nativity, commonly called Christmas, and therefore the 1st of January, of the 46th year of Cæsar, was adopted as the 1st of the Christian era. As the first year of Cæsar was a bissextile, and as every fourth year after the 45th, was a bissextile, consequently the fourth year of the Christian era was a bissextile, and as every fourth year is the one in which the intercalary day is added, we can always determine when this year occurs, by simply dividing the year of the Christian era by 4, if there be no remainder, the year is a bissextile, or leap year, but if a remainder, then that remainder shows how many years it is from the last bissextile. The name leap year is given, because the civil reckoning, which had fallen behind the astronomical, leaps ahead and overtakes it.

The correction introduced into the calendar by Cæsar, would have been sufficient to always keep the astronomical and civil reckoning together, if the fraction of a day over 365 had been just 6 hours, or $\frac{1}{4}$; instead of this, however, it is but 5h, 48m, 51.6s, and the difference is 11m, 8.4s, which, in 4 years, amounts to 44m, 33.6s, by which amount, the fifth civil year begins later than

the astronomical year. In 1582 this difference had accumulated, until it amounted to over 11 days, of course the equinoxes, and solstices, no longer happened on those days which had been appointed to them, and the celebrations of the Church festivals, were consequently much deranged. The Council of Nice, which sat A. D. 325, had decreed that the great festival of Easter, should be celebrated in conformity with the Jewish Passover, which was regulated by the full moon following the vernal equinox. Now the decree did not say that this festival, upon which all the others depend, should be on the first Sunday after the full moon following the vernal equinox, but on the Sunday following the full moon, *on or after the 21st of March*, this being the day, at that time, of the vernal equinox. Pope Gregory XIII., who occupied the pontificate in 1582, determined to rectify this error, which was thus made known, not from any series of observations for that specific purpose, as at the present day, but by the accumulated error becoming so great as to introduce confusion. At this time the vernal equinox really occurred, according to the civil reckoning, on the 11th of March, ten days earlier than the time decreed by the Nicene Council. To remedy this defect, Gregory directed that the day following the 4th of October, 1582, should be reckoned the 15th, instead of the 5th, thus restoring the vernal equinox to its former position, by omitting altogether ten days. To prevent the accumulation, he directed the intercalary day to be omitted on every centurial year; this would have answered every purpose if the difference, which had caused the error, had amounted to a day in 100 years, but it did not, for it was but a little more than $\frac{3}{4}$ of a day, hence omitting the intercalary day every 100th, or centurial year, omitted $\frac{1}{4}$ of a day too much, which, in the course of 400 years, amounts to 1 day. It was, therefore, further provided, that although the intercalary day was ordinarily omitted each centurial year, it was to be retained every 400th year, thus the centurial years 1600, 2000, and 2400, are bissextile; but the years 1500, 1700, 1800, 1900, 2100, 2200, &c., are common years. This correction is sufficiently accurate for all purposes, the slight remaining error will only amount to a day after an interval of 144 centuries. The time of the vernal equinox now is, and always

will be, the 21st of March. The correction introduced into the calendar by Gregory, was not adopted by the English, until the year 1752. At this time the difference between the Julian and Gregorian calendars was 11 days; it would have been 12 days, but the latter had omitted the intercalary day in the year 1700, as we have already stated. It was, therefore, enacted by Parliament, that 11 days should be left out of the month of September of the current year, by calling the day following the 2d of the month the 14th, instead of the 3d. The Greek Church have never adopted this Romish or Latin correction, and consequently, the Russians are now 12 days behind us in their reckoning, and the Christmas festival, which happens with us December 25th, occurs with them January 6th, or Epiphany day, according to our reckoning, and which is sometimes, even now, called "Old Christmas day." The Julian and Gregorian calendars are designated by the terms "Old Style," and "New Style." Thus, by successive improvements, which have been almost forced upon the world, the calendar has been perfected, until it answers all the purposes of civilized life.

"Time," says Young, "is the stuff that life is made of," and we do well, therefore, not to waste such a precious possession. We remember the inscription on the dial in the Temple, at London: "Begone about your business," a wholesome admonition to the loiterer, and the no less appropriate device, once stamped on the old Continental coppers, a dial with the motto, "Mind your business." There is enough to do, and time enough to do all that ought to be done. "There is a time for all things," says Solomon, let us then, be careful and do all things in the proper time. The French Chancellor d' Aguesseau, employed *all* his time. Observing that Madame d' Aguesseau always delayed ten or twelve minutes before she came down to dinner, he composed a work entirely in this time, in order not to loose an instant; the result was, at the end of fifteen years, a book in three large volumes quarto, which went through several editions.

No man, we venture to say, ever accomplished more, and to the better satisfaction of all interested, than Benjamin Franklin, another economiser of time. One of his greatest discoveries was

made in France, and that was, Sun-light was cheaper than lamp-light, and better, too. A severe reprimand, from a man of his standing, and industry, upon the customs of the French court, spending the night in mirth and revelry, and sleeping all the day.

It is said there is a moral in every thing, to the moralizing mind. Since, then, "Time once gone, ne'er returns," let us make the best use of it; not sad, or serious, merely, but sober and reasonable — ready to labor in the hours of labor, and to rest in the hours of rest. We shall not, then, look back on misspent moments, with that feeling so aptly expressed in the German: "*Ach wie nichtig, ach wie flüchtig!*" Ah, how vain, ah, how fleeting!

The flight of Time, which is silently, but surely and uniformly, bearing us from scenes, loved, perhaps, too well, cannot be too accurately marked. The correction of the calendar, by Julius Cæsar, has done more to perpetuate his name than the victories he won for Rome, and the name of Gregory XIII. has more of meaning in it, than that of a mere Saint, in the Romish calendar. There is something pleasing, and yet mournful, in thus minutely contemplating the passage of the year, and we would do well to imitate the good old custom which our forefathers followed, and on the first day of the New Year, make the first entry in our new account books:

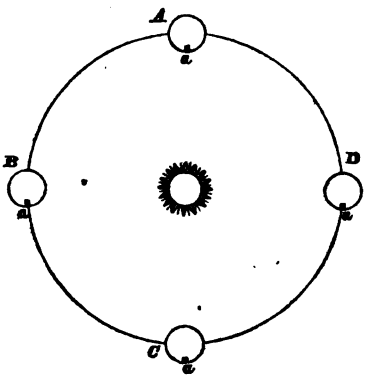
Laus Deo.

CHAPTER VI.

Dials and Dialing.

"This shadow on the Dial's face,
That steals from day to day
With slow, unseen, unceasing pace,
Moments, and months, and years away,
Right onward, with resistless power,
Its stroke shall darken every hour,
Till Nature's race be run,
And Time's last shadow shall eclipse the sun."
J. Montgomery.

In the preceding chapter, we have made frequent use of the word day, and have throughout meant what is called a *mean Solar day*. We have already shown that the Siderial day is the time of an exact revolution of the earth on its axis. This day is shorter than the Solar day, by about 4 minutes. We have also alluded to the apparent motion of the sun in the heavens, showing that if to-day he came to the meridian at the same time with any particular star, to-morrow the star would come to the meridian before the sun, which had apparently changed its place in the heavens. Let us consider to what the difference between Solar and Siderial time is really owing, and see how much the Siderial day should be



shorter than the Solar, to do which we will have recourse to a diagram

Let A B C D, represent the earth's annual orbit, showing the earth in four different positions, and let *a* be the situation of some particular meridian, that of Greenwich, for example. Now, on the supposition that the earth does not rotate on its axis at all, suppose it moving in its orbit, in the order of the letters; it is not difficult to see that the effect will be the same, as though the earth, remaining at rest in its orbit, had turned once on its axis during the year, but in a contrary direction to its present diurnal motion. Thus, while at A, the sun would be on the meridian *a*, but at B, one fourth of a year after, the sun would set *in the east*, and at C, half a year afterwards, it would be midnight at the same meridian, *a*. At D the sun would just begin to rise *in the west*, and finally at A would come to the meridian again. It will now be understood, that although the earth *does* turn on its axis, during its yearly circuit, yet this day as really occurs as if the earth had not the diurnal revolution, hence the number of rotations, measured by the sun's coming to the meridian, will be less than the number as announced by a star, by one day, and therefore the Siderial day must be shorter than a Solar day, by the proportional part of a revolution, which is thus divided up among, and added to the 365 Solar days of the year. Upon the supposition that the mean Solar day is just 24 hours in length, the Siderial day will be, the one-three hundred and sixty-fifth and one-fourth, of 24 hours, shorter, *i. e.* 3m, 56s, very nearly, and a star, in consequence, will come to the meridian 3m, 56s, sooner than the sun, each day, or will gain so much on the sun daily.

We have more than once intimated that the time elapsed between a star's leaving the meridian, to its return to it again, viz: 23h, 56m, 4.01s, is the precise measure of a rotation of the earth, and for this reason astronomers prefer to regulate their time keepers to show what is called Siderial time. Now, suppose to-day to be the 14th of April, which is near the time of vernal equinox, the precise point where the ecliptic intersects the equator, we will imagine to be shown by a bright star. By means of his transit instrument, the astronomer ascertains exactly when this star is on his meridian, and just then sets his clock going, the hands showing at the time 0h, 0m, 0s, and at the same time the town-clock, we

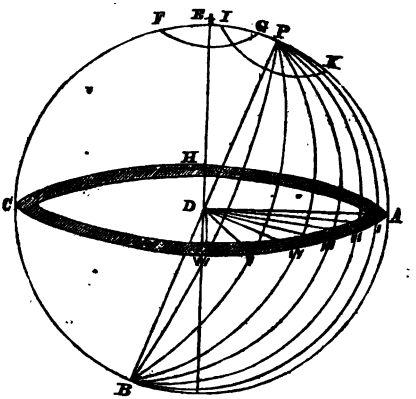
will suppose, or some other time-measurer, such as a watch, or ordinary clock, is set going, showing, also, at that instant, 0h, 0m, 0s. Now the astronomer's clock is, like the other time-keepers, divided into 24 hours, only he reckons straight forward from 1 to 24 hours, while in the ordinary time-piece, the hours are numbered twice in a day, from 1 to 12. We ought to say, however, that the astronomer begins his day at *noon* the 14th of April, while the civil day, April 14th, began at midnight, 12 hours before, but both clocks now show 0h, 0m, 0s. The astronomer's clock has a pendulum a trifle shorter than the common clock, which makes it oscillate somewhat faster, so that the gain, on the ordinary clock, may be about 3m, 56s, in a day. After an interval of 24 hours, by his clock, the astronomer again looks into the transit telescope and sees the supposed star, or equinoctial point, which is always called the first point of Aries, just on his meridian, that is, if his clock is truly adjusted, but it is not yet a day, or 24 hours, by the civil time, but lacks 3m, 56s. The next day the clocks will be still farther apart, and in about 15 days there will be 1 hour's difference, the siderial clock showing 1h, when the ordinary clock shows 12h, or noon; the latter shows the time when the sun is on the meridian, or very nearly so, but the former indicates that the first point of Aries, or the equinoctial point, crossed the meridian an hour before. Now the great convenience to the astronomer is this: As the whole heavens appear to revolve around the earth in a siderial day, he imagines a circle traced out in the heavens, which corresponds to our equator, and, commencing at the vernal equinoctial point, or first point of Aries, he divides this celestial equator, into 24 equal portions, or hours, and these he subdivides into 60 minutes, and each minute into 60 seconds, and he calls the distance of any body from this first point of Aries, measured on the celestial equator, just as we measure longitude on a globe, or map, by ascertaining how far east or west the place is from Greenwich, measured on the terrestrial equator; this he calls the Right Ascension of that body, designated by the initials R. A., and the distance of the body north or south of the equator, he calls Declination, north or south, designated thus: N. D., or S. D., corresponding with our geographical terms, north and south

latitude. The only difference between longitude as reckoned on the earth, and right ascension as measured in the heavens, is, the former is reckoned east or west from any arbitrary point, Greenwich, or Washington, for example, but the latter is reckoned eastward, or in the order of the signs, completely around, and always from the first point of Aries, which is a determined point in the sky, being the position of the vernal equinox, and which turns around, apparently, with the whole celestial concave, in its diurnal revolution.

When a new comet appears, and is announced as having a R. A. of 6h, and 10m, and N. D, of 2° 15′, the astronomer places his transit telescope, or other similar instrument, so as to point 2° 15′ north of the imaginary celestial equator, for he knows just how high above the horizon this is situated, and when his clock points out 6h and 10m, he looks into the telescope and sees the newly discovered object. Thus the precise position occupied by any star, or planet, in the heavens, can be mapped down, using right ascensions and declinations in the same manner as terrestrial longitudes and latitudes. We should like to say a great deal more on this subject, but the nature of our work forbids.

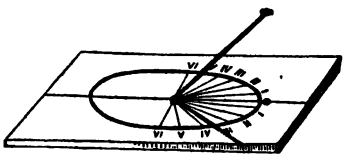
Our ordinary clocks and watches, are adjusted to keep mean solar time. It would, at first, be supposed, that the interval from noon to noon, although longer than a Siderial day, would, nevertheless, be an equal period, so that if a clock was adjusted to show 24 hours during the interval of the sun's leaving the meridian at any particular season of the year, to his return to it the next day, it would always indicate an interval of 24h, for any similar revolution. This is not the case, and we think we can show, very plainly, why it is not. The instant when the sun is actually on the meridian, is called the time of apparent noon, or 12 o'clock apparent time, although, a clock regulated to keep what is called mean time, or mean solar time, may then show but 11h, 45m. The difference between apparent time and mean solar time, is called the equation of time, *i. e.* the correction which must be applied in order to determine true time, from the time indicated by the sun. It is evident that Sun-Dials will indicate apparent time, and we will, therefore, devote the remainder of this chapter

to a description of the principles of dialing, and then proceed to illustrate the causes, which make the discrepancy observed between the times indicated by a clock supposed to run with an uniform motion, and a good sun-dial. We do this the more willingly, for we intend our book to be of some advantage to the reader, and we trust that after its attentive perusal, he will feel sufficiently interested to either erect a good dial, or a meridian mark, in order to determine his local time with something more of accuracy than suffices for the ordinary wants of life. We mean by local time, the correct solar time for the place, in distinction from Greenwich time, or Siderial time. Chronometers, which are accurate, but portable, time-keepers, are often set to Greenwich time, *i. e.* they are adjusted so as to show, wherever they are carried, the actual time then indicated by the clock at Greenwich, the difference between this and the time indicated by the clock at any other place, or the local time will give, by simple inspection, the difference of longitude.



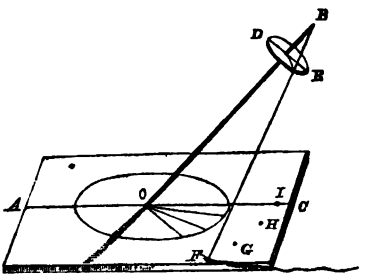
Let P A B C, be the earth, and E the position of a spectator upon it, and let F G be the horizon, or a horizontal circle, and let C H A be the plane of a great circle parallel to the small circle F G, and let P B be the axis of the earth inclined to the diameter

C A of the great circle C H A, according to the latitude of the spectator E. Now as the earth turns once on its axis in 24 hours, it is evident that the several meridians P, P I, P II, P III, &c., will come successively under the sun at exact intervals of 1 hour, if they are all 15° apart, for 24 multiplied into 15 gives 360, the whole number of degrees to the circle. Suppose, for a moment, that instead of the earth turning up on its axis, once in 24 hours, that the sun moves around the earth in this time, the effect will be the same If the sphere of the earth was transparent, but its axis P D B opaque, then P D would, as the sun passed around, cast a shadow in the directions D A, D I, D II, D III, &c., when the sun was in the opposite direction, and the progress of this shadow would mark the hour, according to the meridian in which it should fall. It will be observed, that the intervals A-I, I-II, II-III, are not equal intervals, but vary, because the circle C H A, cuts the meridians obliquely. Now the sun is so far distant, that if the observer at E should locate a horizontal plane, which, of course, would be parallel to the large plane C H A, and describe on it a small circle, and then divide this circle in proportion as the meridians divide the large circle C H A, and should, likewise, erect from its centre a gnomon, or shadow stick, inclined so as to point to the north star, or in other words, to be parallel to P D, the progress of this shadow would mark the hour. We have here,



then, the principle of the horizontal Sun-dial, and all that is necessary to construct one, is, to graduate it proportionally according to the latitude. This can easily be done by calculation, which, however, would involve more of mathematical skill than we shall suppose the reader to possess; we will, therefore, show how it may be done experimentally, and thus any one, with the least ingenuity, can construct a horizontal dial. Referring back

to the figure, page 71, it will not be difficult to perceive that if the circle C H A, had been the equator, then all the angles of the hour lines D A, D I, D II, &c., would have been measured by equal arcs, each 15°. The same would be true of any small circle, I K, parallel to the equator, the meridians, 15° apart, would divide it into 24 equal parts. Now, if on a globe, we should divide any parallel of latitude, such as I K, before alluded to, into 24 equal parts, and then pass a plane, a sheet of paper for example, through each of these divisions and the centre of the globe, then, wherever this plane intersected the plane of any other circle, C H A for example, it would mark out the directions of the hour lines D A, D I, D II, D III, &c. Take, now, a flat board, on which a sheet of paper is fastened, and describe a circle whose centre is O, as in the diagram below, and let O B be a metallic



rod, inclined to the line A C, drawn on the paper to represent a meridian line, at an angle equal to the latitude of the place, let D E be a small circle, so fixed on O B, that its plane is everywhere perpendicular to it, or in other words, so that the distance from the point B to the circumference of the circle, may be the same throughout. Let this smaller circle be graduated into 24 equal parts, and subdivided into halves, and quarters, and if desired, still smaller spaces. Take, now, a fine thread, or a straight edge, and carry it from B through each division of the little circle, successively, down to the plane of the paper below, taking care, if a thread is used, not to crook it against the edge of the little circle, but simply passing it stralght down. Through the points F, G, H,

I, &c., thus indicated on the paper, and the centre of the circle A, draw the hour-lines A F, A G, A H, &c., extending, however, only to the circumference of the circle, and we have a dial ready for use, after adding the figures. Of course the little circle must be so adjusted that when the line is passed by some one of its graduations, it will reach the horizontal plane at a point in the meridian line A C. Instead of a wire for the gnomon, we may use an inclined plane, so that our dial will now be not unlike this

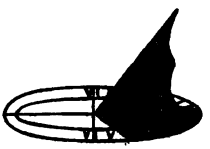


figure. In order to use it, we must next determine the north and south line, or a meridian line, and place the line on our dial which marks XII, to correspond therewith. This may be ascertained by means of a surveyor's compass, provided the variation of the needle from true north is known; or, at the time of the solstices, mid-summer or mid-winter, when the sun's declination is changing very slowly, a number of circles may be traced upon a horizontal plane, having a common centre, over which centre a plumb-line must be suspended, having two or three knots tied in it. Upon marking where the shadow of these knots falls, successively, on the circles, in the forenoon and afternoon, and then bisecting the space so measured on each circle, and drawing a line through the centre and these points of bisection, a pretty exact meridian line may be laid down. The use of several circles, is simply to ensure greater accuracy in the result. We will now suppose the dial constructed, and located in a window facing to the south. We may here observe, that there will be no use in graduating the dial all the way round, as that portion only can be used over which the shadow passes during the day, say from 5 o'clock to 5 o'clock, on each side, viz: from V, on the western side, through VI, VII, VIII, IX, X, XI, to XII, and from XII, to V, on the eastern side. When the sun rises before 6 o'clock, say

at 5 o'clock, it will then be shown at V, by the shadow on the western side of the dial, and the shadow cannot be observed on the dial to advantage much later than 5 o'clock. Suppose, then, the dial located, and that when the shadow indicates XII, or apparent noon, a well regulated clock is started, the hands of which also indicate XII, and this on the 24th day of December, for, as we shall soon see, this is one of the four days in the year when the clock and dial agree, then, although for a few days, the clock and dial will appear to indicate the hour of noon together, it will soon be observed, that the clock begins to gain on the dial, and after an interval of one month, the clock will show 12h, 13m, when the dial indicates noon, or 12 o'clock apparent time. This difference will go on increasing, until February 10th, or 11th, when the clock will appear to lose time, and by the 25th of March will be only 6m. faster than the dial, and on the 15th day of April they will again correspond. The clock, after this, will continue, apparently, to lose time until about May 15th, at which time it will only indicate 11h, 56m, when the dial shows noon; after this, its rate seems to increase, and on the 16th day of June they again come together. The clock now continues to gain on the dial until July 25th, when it is about 6m, 4s, faster, after which, its rate apparently decreases, until at August 31, they again coincide. On the 2d of November, the clock shows 11h, 43m, 46s, when the dial says it is noon; this is the greatest difference of all, being 16m, 14s, after this they begin to come together, and on December 24th, again correspond. Now, can it be that the sun's motion in the heavens, or rather the earth's motion, is thus irregular? We might, at first, suspect our clocks, and watches, but the utmost pains have been bestowed on these, and when their rates of going have been ascertained, by means of the stars, and a transit instrument, as already described, they are found to go perfectly uniform, or very nearly so. Hence we are forced to admit, that the discrepancy between the dial and the clock, is to be sought for in the movements of the earth, and we shall fully show, in our next chapter, what these are.

Thus far we hope we have succeeded in explaining the phenomena of the heavens due to the movements of the earth, and

we have, we trust, been sufficiently clear. If, in some parts, we have been tediously minute, the more intelligent reader will remember we are writing for those who may be less expert. Certainly every one must feel interested in understanding the causes of some of the most striking phenomena which are continually occurring. The varying lengths of days, the annual round of seasons, the constant return of day and night, the tides, the winds, and the clouds, all these force themselves upon observation, and demand some attention. To the consideration and elucidation of these great phenomena, the wisest men of all ages have devoted their lives, and simple and clear as the illustration of these great natural causes may now appear, they have cost an amount of human labor and severe study, which we might in vain attempt to estimate. We feel not the less satisfaction, that we can look beyond the occurrences of the day and understand the causes which are concealed from careless eyes. The earth is no less beautiful, and beloved by us, because we can look above and see worlds, which we know to be a thousand times larger, and on which, we sometimes fancy, myriads of intelligent beings are existing, all pursuing the same great ends as we. After all, we are well satisfied with the study of our own planet, and find enough upon its surface, or below it, to fill us with admiration and wonder, and see enough in it of beauty, whether glowing in the warm sun-light, or reposing in the quiet rays of the moon.

CHAPTER VII.

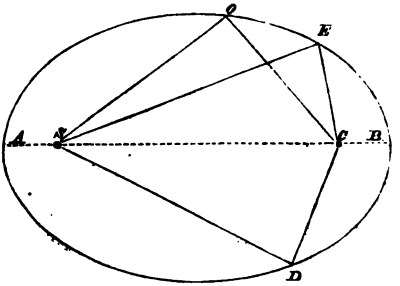
Measurement of Time.

"The Pilots now their rules of art apply,
The mystic needle's devious aim to try;
Along the arch the gradual index slides,
While Phœbus down the vertic circle glides,
Now, seen on ocean's utmost verge to swim,
He sweeps it vibrant with his nether limb.
Their sage experience thus explores the height
And polar distance of the source of light."

Falconer.

HITHERTO we have spoken of the earth's orbit as circular, such being its apparent projection upon the celestial sphere, but this is not the actual case, it is elliptical. This is ascertained by the change in the apparent diameter of the sun, viewed from the earth at different seasons. If the orbit of the earth was a great circle, having the sun in its centre, it is obvious that the angle subtended by his disk would at all times be the same, for his distance from the earth would always be the same. On the contrary, the diameter is observed to increase from the summer solstice to the winter solstice, then to again decrease. It is a proposition established in optics, that the apparent diameter of an object, varies inversely as the distance from the spectator, when the angle is small, hence by observing with great accuracy, the apparent diameter of the sun, at different periods of the year, and actually projecting or calculating the orbit of the earth, it is found to be an ellipse, or oval, as represented in the following diagram. The sun being situated, not in its centre, but nearer one side, in what is called one of the foci of the ellipse. The foci of the ellipse S and C, are so situated on the major, or longer axis, of the ellipse, that the sum of the length of any two lines drawn from the foci to the same point in the circumference of the ellipse is constant. Thus the sum of the lengths C E and S E, are equal to the sum of

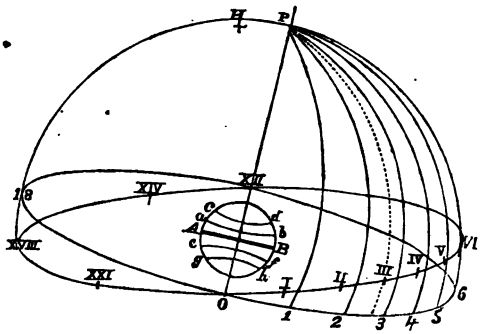
the lengths C O and S O, or C D, and S D, and all are equal to the



length of the major axis A B. By placing two pins, one at each focus of the ellipse, and tying a thread around them of such length as will give the requisite major axis, a true ellipse may be described, by stretching the string and moving a pencil around in the angle. In the preceding diagram, we may suppose S E C, S O C, S D C, to be three positions of the string, the pencil being placed in the angles E, O, and D. Such is the peculiar property of the ellipse, and in such an orbit the earth is moving around the sun. Let S be the position of the sun, and A the position of the earth, at the time when nearest the sun, and when, consequently, the sun's diameter appears the largest. This point in the orbit is called the perihelion point, from two Greek words, which mean near or about the sun. The point B is called the aphelion point, or point away from the sun; when the earth is in this position, the sun's diameter appears the smallest. The line B A, is called the line of the apsides, *i. e.* the line without deviation, or change in length, for we shall show, presently, that whatever changes the earth's orbit may undergo, this line will remain unaltered. In the preceding chapter, we observed that the sun's motion was not uniform in the heavens, or did not correspond with the indications of a well regulated clock. It will not be difficult to understand, that since it is the attraction of the sun which causes the motion of the earth, it will, while approaching the sun, have its motion continually accelerated, or quickened, until it sweeps around the perihelion point A, with its greatest velocity, its motion

will then decrease, and it will move slowest when it passes the aphelion point B. The earth is at the point A, on the 31st of December, and at the point B, six months after, or July 1st. If the inequality between the time indicated by the dial and that by the clock was caused wholly by this change in the velocity of the sun, then the dial and clock should agree exactly when the earth was in these two positions, for the earth occupies just 6 months in moving from A to B, and 6 months in returning from B to A, just what it would if its orbit was a circle, and in which case the dial and clock would agree. But by actual observation, the dial and clock are not together twice in the year, but four times, and then not when the earth is at A and B, December 31, and July 1st, but on December 24th, April 15th, June 16th, and August 31st, as we have already intimated. We must look, therefore, to another source, which, united with the one we have just considered, will fully explain all the observed phenomena, and we find it in the inclination of the sun's apparent path to the equator. As the earth turns on its axis, we may suppose a rod which extends from the centre of the earth, and through its equator to the sky, tracing out a line, or circle, in the heavens, which is called the celestial equator. This circle is, as we have already shown, divided into 24 parts, called hours, each hour comprehending 15°, and all these spaces are exactly equal. If the sun's yearly path in the heavens had corresponded with the equator, or had been in the same plane, then all the difference between the dial and clock would have been simply what was due to his moving sometimes apparently faster than at others, in consequence of the earth's elliptical orbit, but this is not the case, the plane of the ecliptic, or sun's path, is inclined to the plane of the equator. Now, on the supposition that the orbit is circular, let us see what effect this would have upon the sun-dial. In the next diagram, the circle 0, 1, 2, 3, 4, 5, &c., which are hour divisions, represents the equator, and I, II, III, IV, V, VI, &c., which are also hour divisions, the ecliptic. Clock time is measured on the former, for this is the circle, or others parallel to it, in which the stars, and other heavenly bodies, seem to move on account of the diurnal rotation of the earth. Dial time is measured on the ecliptic, and

we have just shown that the dial was graduated, or marked, with



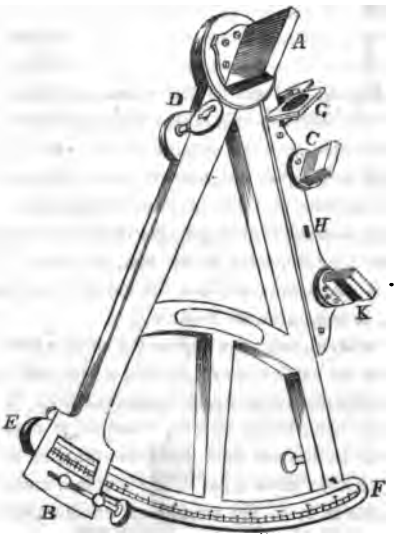
unequal divisions on this very account. The little cross strokes at II, IV, VI, &c., indicate the position of the sun each month from the vernal equinox, P is the north pole of the heavens, and P 1, P 2, P 3, &c. are meridians cutting the ecliptic I, II, &c. above the equator; 0 is the place of vernal equinox, VI the position of the summer solstice, XII the place of the autumnal equinox, and XVIII of the winter solstice. On the 2d day of May, which is about midway between the vernal equinox and the summer solstice, the sun would be at the point III, but if it had moved over three equal divisions of the equator, it would be at 3, and now if a meridian be passed through 3, as at P 3, it will intersect the ecliptic beyond III, *i. e.* on the side towards IV. Now III being the place of the sun, if we suppose a meridian passing through P and III, it will intersect the equator on that side of 3 towards 2, *i. e.* the sun would come to the meridian by the dial before it would by the clock, for the dial will show 12 o'clock, when the meridian, which passes through III, is in the mid-heavens, at any place, but the clock will show 12, when the meridian, which passes through 3, is in the mid-heavens, and this would be after the dial. On the supposition that the earth's orbit is circular, the dial and clock would now, when the sun is at III (May 2d), be farthest apart, after this they would come together and correspond at VI, and 6, the time of the summer solstice, after this the clock would

be faster than the dial till the time of the autumnal equinox, then slower till the winter solstice, and again faster till the vernal equinox. The earth's orbit is not a circle, but if the line of apsides A B, see figure on page 78 corresponded with the line VI-XVIII, in direction, then the clock and dial would agree at the time of winter and summer solstice, *i. e.* December 23, and June 21st, but it does not, for we have seen that the earth is in perigee December 31st, and in apogee July 1st, hence, in forming a table to show the equation of time, *i. e.* the correction that must be applied to the dial, or apparent solar time, in order to obtain true solar, or what is called mean time, which is the time in ordinary use, we must compound the two inequalities, for sometimes when the dial would be fastest, on account of the unequal motion of the sun in his apparent orbit, it would be slowest from the effect of the inclination of the plane of the ecliptic, to the plane of the equator, thus, April 15th, the dial will be slower than the clock, from the inequality of the sun's motion, about 7m, 23s, and at the same time it will be faster, from the obliquity of the ecliptic, about the same amount, hence they are really together on that day. The tables of the equation of time, are thus constructed. We have now explained, somewhat at length, the method of obtaining true time, from the time indicated by the sun, for it is of the utmost importance to the astronomer, and the navigator, to be able, on all occasions, to determine the local time.

It must be evident, that inasmuch as the earth is round, the sun will appear, as the earth turns on its axis, to rise and come to the meridian successively at every point upon its surface. If, therefore, some particular spot, Greenwich for example, is chosen, whose meridian shall be the one from which the time, or longitude, is reckoned, then if we know what time it is at that meridian, when the sun happens to be on the meridian at another place, we can, at once, by taking the difference between the times, viz: noon at that place, and, perhaps 4 o'clock P. M., at Greenwich, determine that it is 4h, west of the meridian of Greenwich, or, allowing 15° to the hour, 60° west. The meridian of Greenwich, where the Royal Observatory is located, is generally acknowledged as the first meridian, and longitude is reckoned east or west from it. In

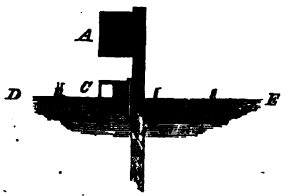
the United States, the meridian of Washington is very often used.

Navigators are accustomed to carry with them Chronometers, or very accurate time-keepers, which are set to Greenwich time, and give, at any moment, by simple inspection, the precise time which is then indicated by the clock at Greenwich. On a clear day, the true time on ship-board, or the exact instant of apparent noon, is ascertained by means of the quadrant, figured below. This is an arc of a circle, embracing something more than one-eighth of the whole circle, but it is graduated into 90°, for the degrees are only half the length they would be, if the angles were measured without being twice reflected.



A is called the index glass; it is a plane quicksilvered glass reflector, placed, by means of adjusting screws, truly perpendicular to the plane of the quadrant, and attached to the brass index arm A B, this index turns on a pin directly under A. C is called the

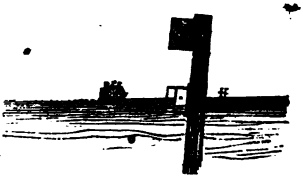
horizon glass, and is also adjusted to be perpendicular to the plane of the quadrant, the upper part of this glass is unsilvered, so that the eye, applied at the eye-hole D, may look through it. The index A B, carries, what is called a vernier, which subdivides the graduations on the limb of the instrument E F, into smaller portions, usually into minutes. When the index is set to 0, and the eye applied at D, the observer will perceive, if he looks through the horizon glass at the horizon, that the portion of the horizon glass which, being silvered, would prevent his looking through, will, nevertheless, show the horizon in it almost as plain as if it was transparent, it being reflected on to it by the index glass A, and then again reflected to the eye, thus, Fig. 1, A is the index



(Fig. 1).

(Fig. 2).

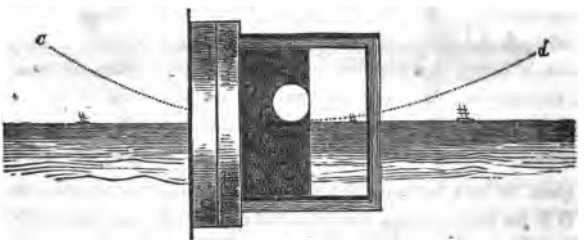
glass, its back being towards the eye, and C the horizon glass, and D E the horizon, seen almost as plain in the silvered portion of C, as through the transparent part. If the glasses are all rightly adjusted, then, even if the position of the quadrant be altered, as in Fig. 2, the line of the horizon will still be unbroken, but move the index ever so little towards 1°, or 2°, and immediately the reflected image of the horizon will sink down, as shown in this diagram,



a space equal to that moved over by the index, and if a star should happen to be just so many degrees, or parts of a degree, above

the horizon, as the index had been moved, and as shown at *a*, it

would appear in the quadrant, as in the figure preceding, brought to the line of the horizon. Now just before noon, on ship-board, the sailor sets the index of his quadrant to about the altitude of the sun, and defending the eye by a set of dark glasses, shown at G, page 82 he looks through the eye-hole D, and the unsilvered portion of the horizon glass, and sees a distinct image of the sun, almost touching the horizon, thus :



It is true, he cannot see the horizon in the silvered portion of the horizon glass, but he can bring the image close to the line where the silvering is removed from the glass, and then by inclining his quadrant a little, as in figure 2, page 83, he can make the sun, apparently, describe the dotted arc *c d*, just touching the horizon. We will suppose he is looking just before noon, *i. e.* before the sun comes to the meridian, or reaches his highest altitude in the heavens, and that an assistant stands near, ready to note the time when this highest point is reached. As he looks through his quadrant, the image of the sun, which a moment before described the arc *c d*, and appeared to touch the horizon in its course, will seem to rise a little, he therefore moves the index, and brings it down again, all the time sweeping backward and forwards ; if it rises a little more, he again brings it down; very soon he perceives

it to be changing its position scarcely at all, and gives notice to the person with the watch, or chronometer, to be ready; in a moment, instead of rising, as before, it begins to dip below the horizon, and he calls out, and the time is accurately noted. This is the exact instant of 12 o'clock, apparent time, or the instant when the sun, having reached its highest point, begins to decline. Now the chronometer, with which he has been observing, does not say 12 o'clock, but perhaps, 3h. 5m. 10s. in the afternoon. We will suppose the observation to be made on the 27th day of August. On this day, as will appear from a table showing the equation of time, a clock adjusted to keep true solar time, should show 12h, 1m. 10s. at apparent noon, and this is the time which the clock would show at Greenwich, at apparent noon there upon this day; but when it is apparent noon at the place where we have just supposed an observation made, the Greenwich clock shows 3h. 5m. 10s., the difference is 3h. 4m., which, allowing 15° for each hour, indicates that the observation is made in a place 46° west of Greenwich. It is west, because the sun comes to the meridian later than at Greenwich. Now if the latitude was known by observing the altitude of the polar star, then, by referring to a chart, the position, either on ocean or land, where the observation was made, could be indicated; for all charts, or globes, which represent the earth's surface, have lines drawn upon them, through the poles, called meridians, showing every degree east or west of Greenwich, and also every degree north or south of the equator.

We will close this somewhat tedious chapter, with an allusion to a circumstance which has sometimes puzzled the uninitiated, viz: two ships may meet at sea and vary in their reckoning a day or two. Suppose a traveler, leaving New York on a certain day, to travel continually east, until after a certain time, one year, or perhaps twenty, he arrives at the place from which he started; and farther, suppose he has kept an accurate note of the number of days which has intervened. For every 15° he has traveled east, the sun has risen one hour earlier to him than to those left behind. This gain, by the time he has traveled 360°, amounts to a whole day, and when he arrives home he finds his reckoning one day in advance of his neighbors, or in other words, he has

seen the sun rise once more than they have. The year to him has consisted of 366 days, but to his neighbors of only 365. Now, what is not at all an improbable case, we will suppose him arriving home on a leap year, on the 28th day of February, and which he calls Sunday, the 29th, but those who have remained at home call it Saturday. The next day, February 29th, is, according to them, Sunday; here is another Sunday in February, but there have already been four others, viz: the 1st, the 8th, the 15th, and the 22d, making six Sundays in this shortest month. It is said that this case has actually occurred; that a ship left New York on Sunday, February 1st, and sailing eastward continually, arrived home, according to her log-book, on Sunday, the last day in the same month, but really on Saturday, according to the reckoning at home. The next day, being the intercalary day, made the 28th, and 29th both, Sundays to the voyagers; thus giving six Sundays to the month. If, on the contrary, a voyage had been made westward, one day would have been lost in the reckoning, as the sun would rise one hour later for each 15°, and if two travelers should leave the same place, say on Tuesday, and each, after passing completely around the globe, the one east, and the other west, should again meet at the same place, there would be a difference of two days in their account, the one calling the day Monday and the other Wednesday, when, in reality, it would be Tuesday.

CHAPTER VII.

Chronology.

"Brightly ye burn on heaven's brow;
Ye shot a ray as bright as now,
When mirrored on the unruffled wave
That whelmed earth's millions to one grave."

E. P. Mason.

We have more than once mentioned the importance of the movements of the heavenly bodies, in determining certain chronological questions, and will now give some farther illustrations of this subject. The precession of the equinoxes, and the occurrence of solar and lunar eclipses, are the two astronomical events which have been of most essential service. We have, in the preceding pages, illustrated the precession of the equinoxes, showing that the places of vernal and autumnal equinox, or the points where the ecliptic intersects the plane of the equator, moved westward at the rate of 50½ seconds of arc in one year. The phenomena of solar and lunar eclipses, we have not explained, nor does it fall within the limits we have prescribed to our little volume, to embrace them. We shall, therefore, only refer at present, to the service which chronology has received from the knowledge of the retrogradation of the nodes of the earth's orbit, on the ecliptic. As already shown, the path of the ecliptic in the heavens, is divided into 12 equal parts, of 30° each, called signs, and these signs formerly gave the names to the constellations, or groups of stars near which they were located, when the ecliptic was thus first divided or portioned out. That point in the ecliptic where the vernal equinox is located, was then, and has been always, designated as the first point of Aries, but as this equinoctial point changes its position, moving contrary to the order of the signs in the ecliptic, at the rate of 50.2 seconds a year, the first point of the sign Aries no longer corresponds with that group of

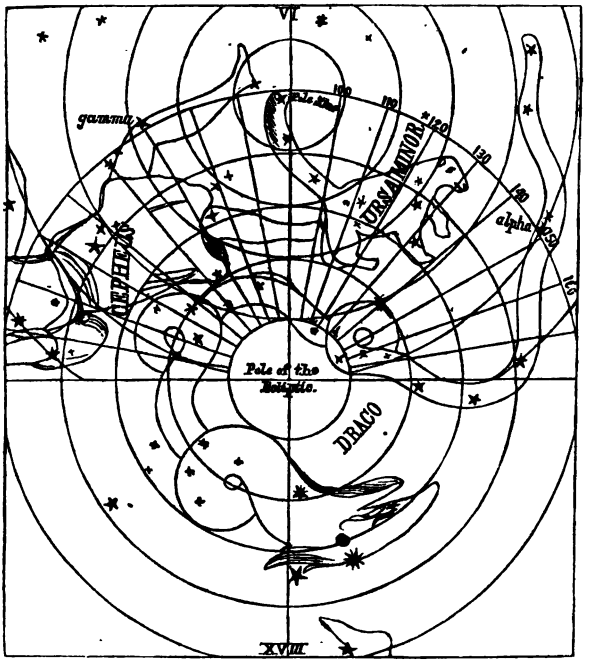
stars to which it formerly gave a name, for the shifting of the equinox cannot carry forward the stars with it. The vernal equinoctial point is now situated in the constellation Pisces, having altered its position about 30° since the constellations were grouped and named in their present order. As we know the annual amount of the precession, we can determine how long ago the present zodiac was formed, viz:

$$50.2'' : 1 \text{ year} :: 30^\circ (=108{,}000'') : 2155.6 \text{ years},$$

that is, about 300 years before the Christian era, when the most celebrated astronomical school of antiquity, flourished under the auspices of the Ptolemies, and the labors of the astronomers of that school, the most celebrated of whom was Hipparchus, who formed a catalogue of the stars, were recorded in the *Almagest* of Ptolemy, and constituted the chief knowledge upon this subject, until the times of Kepler, Tycho Brahe and Copernicus. The conclusions which we may come to, from ancient astronomical observations, are necessarily liable to some error, from the imperfect manner in which their observations were made, most of them having been but approximations, and not very close ones, to the truth. We have illustrated, (page 60), in what manner the precession of the equinoxes causes the pole of the heavens to revolve around the pole of the ecliptic, the effect of which is, that successive stars, which lie in the circumference of the circle which the pole of the heavens thus describes, will, in succession, become the pole star. The present polar star was not always the pole star, nor is it as near the true pole of the heavens now, as it will be. In about 240 years, it will be but $29' 55''$ distant from the pole. At the time of the earliest catalogues, it was 12° distant, and now, 1848, its distance is about $1^\circ 25'$. About 2900 years before the commencement of the Christian era, the bright star in the tail of Draco, called Alpha, was the polar star, and was then only $10'$ from the pole; and in 11,600 years, the bright star Lyra, will become the polar star, and will then be but 5° from the pole, whereas, its distance now is upwards of 51°. We give on the next page, a representation of that part of the heavens where the north pole of the ecliptic is situated.

Here we have the pole of the ecliptic in the centre, and the

pole of the heavens, or that part of the heavens towards which the pole of the earth points, at the top, directly where the line VI-XVIII crosses the outermost circle drawn around the pole of the ecliptic, and which is the little circle represented in the figure, (page 59), with the radius T S, or T Z. The pole of the earth, as



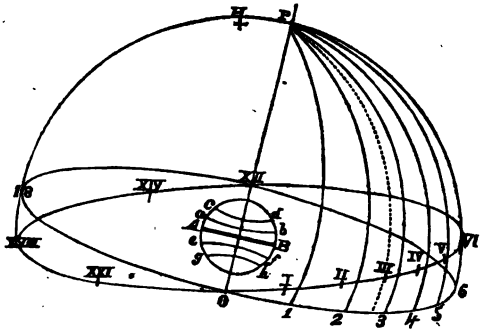
it revolves around the pole of the ecliptic, passes, in succession, through each point of this circle, moving, as represented in the map, towards the left. This circle we have graduated into spaces of ten degrees each, and drawn meridians from the pole of the ecliptic through them, the pole of the heavens moves over one of these spaces in about 718 years. The meridian VI, XVIII, is the only one which passes through the two poles, consequently when Polaris comes to this meridian, its distance from the pole will be the least possible. In the course of 2100 years, as will be perceived,

the star called Gamma, in the constellation Cepheus, will be the pole star. The meridian VI, XVIII, is called the solstitial colure, because it is the meridian which passes through the highest and lowest points of the ecliptic, which are called solstices, being the meridian 18, P, 6, of the figure on page 91.

We will now give some instances of the application of the precession of the equinoxes to chronology. Eudoxus, a celebrated Greek astronomer, informs us, that in the celestial sphere, he had observed a star which corresponded to the pole of the equator. From various circumstances, we know Eudoxus lived about the fourth century before Christ, hence it could not be our present polar star which he observed, for at that time it was too far removed from the pole. Upon reckoning back about 2000 years, however, upon our map, we find a small star of the fifth magnitude, which may be the one observed by Eudoxus. We are of opinion that this star is the one meant by him. Others, however, supposing Eudoxus to have borrowed his sphere from some older source, have selected Kappa, in the constellation Draco, as the star. This latter was the pole star about 1310 years before Christ, but in the time of Eudoxus, it was as far distant from the pole, nearly, as was our present polar star. The little star we have been considering, was the pole star about 200 years before the Christian era, and as it is easily visible to the unassisted eye, was probably the star meant by Eudoxus.

The effect of the precession of the equinoxes, is to change the right ascensions and declinations of the stars, for, as we have more than once observed, right ascension is the distance from the first point of Aries, but this point is continually changing its place in the heavens. It also changes what is called the longitude of the stars. The longitude of a star, is, like right ascension, reckoned from the first point of Aries eastward, but upon the *ecliptic* instead of the equator, thus, 0° of R. A. and 0° of Long. are both reckoned from the same point. See the next figure, where the right ascension is marked 0, 1, 2, 3, 4, &c., and longitude is marked 0, I, II, III, IV, &c. Declination is distance north or south of the equator, but latitude is distance north or south of the ecliptic, hence, when a star happens to be in the

meridian called the equinoctial colure, or meridian which passes through the equinoxes, a part of which meridian is seen at P O, its



declination and latitude will be pretty near the same, but if the star happens to be in the solstitial colure, the latitude will vary from the declination, by the amount due to the obliquity of the ecliptic, being either more, or less, according to the position of the star, and whether the latitude is reckoned north or south. It will also appear that the latitude of a star is not altered by precession. Imagine, for a moment, the system of meridians, and the ecliptic and equator, entirely detached from the stars, and moved slowly around, not the pole of the earth, which we will imagine within it, but the pole of the ecliptic H. It is easy to conceive that a star which is in the equator, say at the point 2, would no longer be in it, but a star at II, in the ecliptic, although its distance from the vernal equinox would be increased, would still be in the ecliptic. The same is true of all small circles parallel to the equator and ecliptic, the former called declination circles, and the latter parallels of latitude. Perhaps we have been tediously minute, but there is some satisfaction in understanding a difficult subject, and if the reader has had like patience with ourselves, we trust the time will not be spent in vain. The grand point at which we have been aiming, after all, is this; if we can find any ancient records of observations which give the longitudes of the stars, we can tell the dates of the observations. It is well known that the ancients did not possess a uniform system of chronology

like ourselves, but they endeavored to perpetuate the memory of great events by recording the positions of the heavenly bodies at the time; and in this, at least, they exhibited wisdom. We find continual evidences of this, particularly in the poets of those early ages. The Egyptians, to whom the overflowing of the Nile was an annual, and in some respects, a dreaded occurrence, were accustomed to watch for the heliacal rising of the dog-star, which warned them to gather their wandering flocks and herds, and prepare for the coming flood. Hence, that star was called Thoth, the watch-dog, the Guardian of Egypt.

The stars rise or set heliacally, when they rise just before, or set just after the sun. They are said to rise or set cosmically, when they rise or set just at sunrise, and to rise or set acronycally when they rise or set just at sunset. It will appear that the heliacal rising, or setting, will precede or follow the cosmical rising, or the acronycal setting, by about 12 or 15 days, for a star cannot be seen unless the sun is 12° or 15° below the horizon, and the sun moves over about a degree in a day. Pliny says that Thales, the Miletian astronomer, determined the cosmical setting of the Pleiades to be 25 days after the autumnal equinox. At the present time, the same event occurs about 60 days after the equinox, making a difference of 35 days, which, allowing 59′ to a day, makes 34° 25′ change in longitude, due to the precession of the equinoxes. This, divided by the annual precession, 50.2″, gives about 2465 years since the time of Thales, or 620 years before Christ. We find, also, in Hesiod, the number of days after the winter solstice, when Arcturus rose acronycally,

> "When from the solstice sixty wintry days
> Their turns have finish'd, mark, with glitt'ring rays,
> From Ocean's sacred flood, Arcturus rise,
> Then first to gild the dusky evening skies."

But as we know the latitude of Bœotia, where Hesiod lived, we can determine the acronycal rising of Arcturus, and by means of the difference between the time now, and the time mentioned by him, which is due to precession, can determine the age in which he flourished. From actual observation, it is ascertained that now this star rises at sunset about 100 days after the winter solstice.

The difference, 40 days, converted into degrees, allowing 59′ for a day, is 39°, very nearly; dividing this by the annual precession 50.2″, gives 2796 years since he flourished, or about 950 years before the Christian era. Meton, the famous astronomer of Athens, says that the star Beta Arietis, was in the vernal equinox in his time, but at the commencement of the present century its longitude was 31°, 10′, 44″, this divided by the annual precession, gives 2236 years from the time of Meton's observations to the commencement of the 19th century, or 436 years before Christ. If we know the year in which any event occurred, we are frequently enabled to tell nearly the day on which that event transpired. Thus, Thucydides tells us that the investment of Platea, during the fifth year of the Peloponnesian war, which was 426 years before the Christian era, occurred about the time of the heliacal rising of Arcturus. But the heliacal rising of Arcturus then occurred in the month of August, and hence we are enabled to not only give the year, but nearly the month when this event occurred. And we may here remark, that the beginning of the Peloponnesian war, is itself, determined to be 431 years before Christ, by means of an eclipse of the moon which occurred, as can be most accurately calculated, April 25th. In the same year, on the 3d of August, an eclipse of the sun was visible at Athens, concerning which, Thucydides, the celebrated Greek historian, remarks: that a solar eclipse happened on a summer's day, on the afternoon, in the first year of the Peloponnesian war, so great that the stars appeared.

"We are apt to undervalue the science of the ancients; we ought rather to look upon it with respect and admiration. It is truly astonishing that with their imperfect instruments, they arrived at so much accuracy in their astronomical calculations. The very want of instruments led to an intensity of observation much greater than ours. As the savage inhabitant of the forest without a compass, marks his course through the pathless wilds with an accuracy far beyond that of the civilized man, so at a very early period of the world's history, did even barbarous nations learn by the rising and setting of the constellations to regulate the course of the year. However rude therefore, the Romans under

Romulus may have been, it was impossible for them to depart greatly from the tropical year; because they watched the constellations, and connected with their rising and setting the seasons of agriculture, and the times of their religious festivals. Any alterations would be quickly perceived and the very observances of a religion, the gods of which presided over their secular employments, served as a balance-wheel to regulate the movements of their chronology."

We shall conclude this chapter with some account of the Zodiacs discovered by the scientific men who accompanied the French expedition to Egypt, and which were thought to give an age to the world much greater than the generally received system of chronology. We may here remark, that the evidence appears from other sources, to be pretty conclusive, that man has not inhabited the globe for more than about 6000 years, although the evidence is equally strong, that the globe itself, is, perhaps, millions of years old, and has been inhabited by a race of animals, and covered with a vegetation, entirely unknown at present. During the campaigns of the French army in Egypt, a Planisphere and Zodiac were discovered by Mons. V. Denon in the Great Temple of Dendera, or Tentyra, and copied in his "*Voyage dans la Basse et la Haute Egypte, pendant les Campagnes du General Bonaparte.*" *Paris*, 1802, Fol. Vol. II. Plates, 130, 131, 132. Dendera, anciently the large city of Tentyra, is a town of Upper Egypt, situated at the edge of a small but fertile plain, about a mile from the left bank of the Nile, and 242 miles south of Cairo. Its Temple, magnificent even in ruins, is the first that the Egyptian traveler discovers on ascending the Nile; it is 265 feet in length and 140 feet in breadth, and has 180 windows, through each of which the sun enters in rotation, and then returns in a retrograde direction. The front of the Temple is adorned with a beautiful cornice and frieze, covered with hieroglyphics, over the centre of which is the winged globe; while the sides are decorated with compartments of sacrifices. In the front of the building is a massive portico, supported by 24 immense columns, in four rows, having circular shafts covered with hieroglyphics, square capitals resembling Egyptian Temples supported by four human heads

horned, and round foliated bases on square plinths. On the ceiling of this portico is the large Zodiac, partly carved and partly painted in natural colors, on a blue ground studded with yellow stars. The general design of the Zodiac is divided in two, and represents two female figures, which bend over the divisions, typical of Isis, or the year; with a winged globe placed against each, allusive to the sun entering his course. Each band of the Zodiac is divided into two, by a broad line covered with smaller hieroglyphics. On the upper division of the Zodiac, which is the broadest, are represented six of the Zodiacal signs; and under them, in the second division of the top band, are 19 boats, each carrying a figure significative of some astronomical appearance; accompanied by an Egyptian inscription in a square. The constellations, and other heavenly bodies, were the Divinities of Egypt, and it was supposed that they performed their revolutions in boats. The other great band contains the six remaining signs of the Zodiac; and on its lower division are 19 other boats, as before. The Rev. Samuel Henley, in his very instructive and highly erudite remarks on this Zodiac, published in the Monthly and Philosophical Magazines, says, that these boats signify the nineteen years of the Metonic, or Lunar Cycle, which contains 6940 days; after which, the New and Full Moons, and other Aspects, are supposed to return to the same day of the Julian year. The smaller Zodiac, or rather Planisphere, is carved on the ceiling of a separate quadrangular apartment on the east side of the Temple. It is of a circular form, and is supported by four human figures, standing, and eight kneeling, who have hawks heads. In both these Zodiacs the equinoctial points are in the constellation Leo, and it was by some inferred that they were constructed at the time when the sun entered this constellation at the equinox, or more than 9,700 years ago; about 4,000 years before the Mosaic record. These Zodiacs were brought away, and exhibited in the Louvre at Paris; and for a long time were the occasion of much discussion. All the speculations of infidel philosophers were, however, scattered to the winds by the discoveries of Champollion; and the dissertations of Visconti and Henley have proved, in opposition to the infidel arguments of Ripaud, Petau and Archer, that they are of

the age of Augustus Cæsar; and that they were erected in the Julian Year 4695, which then regulated the Egyptian, twenty-four years before the actual birth of our Savior, and twenty-eight years before the common era. All this is confirmed by the following Greek inscription, over the outer or southern portal of the Temple: — "On account of the Emperor Cæsar, God, the son of Jupiter, the Deliverer, when Publius Octavius being Governor, Marcus Claudius Posthumus Commander in Chief, and Tryphon General, the Deputies of the Metropolis consecrated, in virtue of the Law, the Propylæum to Isis, the greatest of Goddesses, and to the associated Gods on the Sacred Thoth." The Country of Egypt, had at that time become a Romish Province; and Augustus Cæsar, in the 31st year of his age and the 725th year of Rome, ordained that the Egyptian Thoth should for ever commence on the 29th of August.

CHAPTER VIII.

The Seasons.

"For this the golden sun the earth divides,
And, wheel'd through twelve bright signs, his chariot guides,
Five zones the heaven surround; the centre glows
With fire unquench'd and suns without repose:
At each extreme, the poles in tempest tost,
Dark with thick showers and unremitting frost:
Between the poles and blazing zone confined,
Lie climes to feeble man by Heaven assigned.
'Mid these the signs their course obliquely run,
And star the figured belt that binds the sun."

Sotheby's Virgil.

We have, at length, arrived at that part of our work, which will treat upon and explain the phenomena of the seasons. All that we have said in the preceding chapters, has been preparatory to this, and, we trust, that there will not be less of beauty, or poetry, in our contemplations of those great changes which mark the rolling year, because we can understand the causes which produce them. To our own mind, there is no subject more delightful than this, of the changing year; a theme, which is perhaps, still more endeared to us by the beautiful poetry of a Thompson, a Bloomfield, and a Cowper. A theme, which, even to Chaucer, and Spenser, and Shakspeare, and Milton, was a passion.

After the somewhat tedious detail and explanation, which has preceded, we feel, on approaching this always interesting subject, as Milton expresses it,

"As one who long in populous cities pent,
Where houses thick and sewers annoy the air,
Forth issuing on a summer morn, to breathe
Among the pleasant villages and farms."

To behold Nature as she is, and see the glorious changes which she wears, from the unsullied mantle of winter to the russet garb of autumn, we must quit the busy haunts of men, and leaving the

noisy streets and smoky cities, seek the country fields, and lanes. We have been much struck with a remark of Howitt, in his "Book of the Seasons," in which he thus deprecates the necessity that deprives our childhood of a contemplation of those beautiful changes which mark the year. "Oh that I could but touch a thousand bosoms with that melancholy which often visits mine, when I behold little children endeavoring to extract amusement from the very dust, and straws, and pebbles of squalid alleys, shut out from the free and glorious countenance of Nature, and think how differently the children of the peasantry are passing the golden hours of childhood; wandering with bare heads, and unshod feet, perhaps, but singing a 'childish, wordless melody,' through vernal lanes, or prying into a thousand sylvan, leafy nooks, by the liquid music of running waters, amidst the fragrant heath, or on the flowery lap of the meadow, occupied with winged wonders without end. Oh! that I could but baptize every heart with the sympathetic feeling of what the city pent child is condemned to lose; how blank, and poor, and joyless must be the images which fill its infant bosom, to that of the country one, whose mind

> Will be a mansion for all lovely forms,
> His memory be a dwelling-place
> For all sweet sounds and harmonies!"

In the absence of a system of chronology to mark the returning periods of nature, the ancients were obliged to note the aspects of the stars. We have several times, in the preceding pages, referred to this, and we may now remark, that some of the most beautiful passages of the ancient poets, contain allusions to the stars as connected with agriculture. Hesiod, the oldest poet of the Greeks, has given a minute detail of the heliacal rising of the stars, accompanied with the most pleasing descriptions of the successive occupations of rural life. The name of the poem is, "*Opera et Dies*," the Works and Days. This poem Virgil has imitated, in the first and second "Georgics;" a word compounded of two Greek words, and meaning, works or labors of the earth, and corresponding almost exactly with our word agriculture. We shall give occasional quotations from both these poems, in our present chapter.

In the absence of a correct calendar, such as our almanacs now furnish, the early cultivators of the soil very wisely determined the recurrence of various seasons, by the aspect of the heavens. It was, to them, a matter of no small importance, to know, with unerring certainty, the time when first to break the soil, and plant. This they could not do, judging from the simple change in the climate, or temperature, due to the return of spring; as various causes, which we need not mention, render this indication liable to great uncertainty. Hence, at a very early day, the apparent path of the sun, in the heavens, was divided into twelve portions, called signs; and as these signs were mostly representatives of living objects, it was called the *Zodiac*, from a Greek word meaning life. In a previous chapter, we have shown how this division was accomplished by means of the water-clock. The present division of the Zodiac was probably made by the Egyptians, and they named the signs with particular reference to agriculture, and the seasons at the time of their invention. From the Egyptians it was undoubtedly borrowed by the Greeks, and from them has been transmitted to us. As we have elsewhere shown, these signs are reckoned from the point of vernal equinox, or first point of Aries, eastward, completely around the ecliptic. Their names are, *Aries*, *Taurus*, *Gemini*, *Cancer*, *Leo*, *Virgo*, *Libra*, *Scorpio*, *Sagittarius*, *Capricornus*, *Aquarius*, *Pisces*. The sun enters Aries, or the Ram, at the time of vernal equinox; hence this sign was represented under the form of a ram, to which the character ♈ was placed, designed no doubt, at first, to represent a ram's horns. This was the beginning of spring. The sun entered the next sign, Taurus, a Bull, a month afterwards; which was, therefore, appropriately represented by a bull, the attention now being drawn to plowing and sowing. This sign was once situated in the *constellation* Taurus, which numbers among its stars the beautiful group called the Pleiades, or seven stars, although now, on account of the precession of the equinoxes, it is in the *constellation* Aries. Hesiod alludes to the heliacal rising and cosmical setting of the seven stars:

> "When, Atlas born, the Pleiad stars arise,
> Before the sun, above the dawning skies,
> 'Tis time to reap; and when they sink below
> The morn illumined west, 'tis time to sow."

And we find in Job an allusion to the Pleiades, as harbingers of spring: "Canst thou bind the sweet influences of the Pleiades," &c. [Job 38: 31]. The symbol of Taurus is ♉, once intended for a bull's head and horns. The sign Gemini, or the Twins, which the sun enters two months after the commencement of spring, was denoted by the symbol ♊, intended to represent the twin sons of Leda; as this was the month when the flocks brought forth, this sign was adopted as the harbinger of a fruitful increase. The next sign is Cancer, the Crab, the sun enters this sign at the time of the summer solstice, or at midsummer. Previous to entering this sign, it had been rising, each day, higher and higher, until now, having reached its highest point, it begins to return; hence the sign, a crab, an animal fabled to run backwards as well as forwards, and its symbol ♋, is intended to illustrate this. In the Zodiacs discovered at Dendera and Esne, alluded to in the last chapter, the place of this sign is occupied by a *Scarabeus*, or Beetle; but in the Hindoo Zodiac, which was probably borrowed from the Chaldeans, and is therefore older than the Egyptian, we find the figure of a crab. It will be understood that these divisions of the ecliptic, which heretofore we have marked as hours, see the figure, page 91, are the commencement and middle of the twelve signs, each sign comprehending two hours, 0 corresponding to the first point of Aries, II the first point of Taurus, &c. It will be noticed that the sun reaches the highest point of his orbit at VI, or the first point of Cancer, where the solstitial colure intersects the ecliptic.

The fifth sign is Leo, the Lion. The sun entered this sign about the time of the overflowing of the Nile, at which period, the lions, driven from the interior by the heat, hunted along its banks. This sign is figured in the Egyptian and Indian Zodiacs very near as we have it now. The symbol is ♌, probably a corruption of an hieroglyphical character, intended for a crouching lion. The next month, the sun entered Virgo, the virgin. This was the harvest month, and hence was appropriately represented by a virgin with a sheaf of wheat. The Egyptians represented it under the figure of Isis; the symbol is ♍. This is probably an hieroglyphical character. The next sign is Libra, the balance,

represented by a scale-beam ♎. The sun enters this sign at the time of the autumnal equinox, when the days and nights become nearly equal all over the world, as we shall soon explain. Virgil alludes to this constellation :

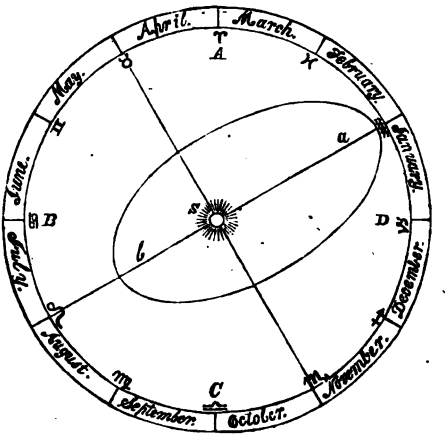
> "When poising Libra rest and labor weighs,
> And parts with equal balance nights and days,
> Goad, goad the steer, the barley seed enclose,
> Till winter binds the ground in dead repose."

The next month, abounding with venemous reptiles, was characterized by the sign Scorpio, a scorpion, though in some of the old Zodiacs it is represented under the form of a snake, or an alligator; its symbol is ♏. The next sign is represented, in all the Zodiacs, under the form of a hunter, or archer, as the sun enters this sign in November, the hunting month, and its symbol is an arrow ♐. When the sun enters the next sign, about the latter part of December, it is mid-winter, and the time of the winter solstice, the sun being at the position marked XVIII, see the figure, page 91. It is represented under the form of a goat, for now the sun, having reached its lowest southern declination, begins to climb up in the heavens, like the goat climbing the mountain steeps; the symbol is ♑. The next sign is represented by Aquarius, the water-pourer, perhaps in allusion to the rainy season, and the symbol ♒, is intended, no doubt, to represent the water, or waves. The last sign is Pisces, the fishes, represented by the symbol ♓, and the constellation is usually figured in the heavens as two fishes tied by their tails, for the earth being now bound in winter's icy chains, subsistence is derived from the streams.

Such are the twelve signs of the Zodiac, and through one of these the sun passes each month, and thus their names, become to us, indicative of months, Aries corresponding with March, Taurus with April, &c. When the sun enters one sign the earth enters the opposite, as in the following diagram.

Thus, when the earth enters the sign Libra at C, at the time of the vernal equinox, the sun, S, appears to enter the opposite sign. Aries, at A, and when the earth arriving at D, enters the sign Capricornus, at the time of the summer solstice, the sun enters

the opposite sign, Cancer, at B. Hence, whatever sign the sun



may be in, the opposite sign will rise at sunset, being 180°, or half a circle, distant from the sun. If the orbit of the earth was a true circle, the progress of the sun through the signs would be performed with an equable motion ; but this is not the case, as we have shown when speaking of the equation of time. Its orbit is elliptical, and its major axis lies in the direction of a line joining the beginning of August and January, nearly, so that the sun is actually nearer the earth in January than in August. We shall see, presently, why its rays, at that time, have less effect in warming the earth, in our northern climates than in summer. On account of the proximity of the earth, to the sun, in winter, and its consequent swifter motion ; the sun will appear to move through the winter signs faster than through the summer signs, and will therefore accomplish the six winter signs quicker than the six summer signs. Hence, the winter is always, in any latitude north of the equator, shorter than the summer. This difference amounts, in the temperate zones, to almost eight days. At all places south of the equator it is summer, when it is winter in the northern hemisphere, as we shall now proceed to show, and hence the summer there is shorter than the winter, for the sun is

nearest those places in summer. And those signs, which are winter signs to us, who live in the northern hemisphere, are summer signs to the inhabitants of the southern. All varieties of seasons are thus, at all times, upon our globe. When one portion is covered with the white mantle of winter, another is producing beautiful flowers. At one place spring is commencing, at another the autumn, and around the equatorial regions of the earth perpetual summer reigns. Perhaps there is nothing that seems more strange to the traveler, than this variety of seasons from change of latitude. The names of the winter months, which so long have been associated with ideas of cold, and frost, and storm, seem strangely misplaced, when he beholds flowers blooming around him in December, and hears the songs of birds wafted on the light breeze. Christmas and New Years, which in our northern country, are wont to be associated with the cheerful blaze, the merry sleigh-ride, or the drifting snow, bring no such associations to the inhabitant of the southern hemisphere; there, mid-summer reigns, and the cool breezes, which blow over the Indian seas, laden with perfume, dispel the sultry heat. The cause by which all this variety is produced, is not the less interesting because it is simple, and because we see in it a guaranty that long as time shall last, or the present race inhabit the globe, so long the seed time and harvest must return with undeviating certainty.

We have mentioned formerly that the earth's orbit is an ellipse, and that the longer or major axis of the ellipse is called the line of the apsides. We might have shown that between the limits of an ellipse, viz: a perfect circle on the one hand and a straight line on the other, this orbit might vary, but still the periodic time of a revolution remain unchanged. But these are theoretical investigations upon which we cannot enter. We will, however, observe that the line of the apsides, or major axis of the earth's orbit, is its most important element, for when this is determined the periodic time of a revolution, and the mean distance from the sun are also determined. The orbit itself, under the influence of various forces, may change its ellipticity, expanding towards a circle on the one hand, or diminishing towards a straight line on the other, or the ellipse may swing round upon

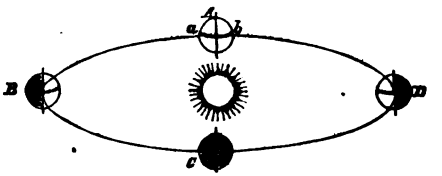
this line, altering its position in space; but amidst all these changes, the line of the apsides knows no change. Its length remains the same notwithstanding all the perturbations of the planets, and all the changes to which the rest of the orbit may be subjected. The eccentricity of the earth's orbit is now slowly changing, diminishing at the rate of about 11″ in a century, on account of the mutual gravitation of the planets. It will continue to diminish for centuries, and it is somewhat curious that this dimunition is indicated by the movements of the moon, for it produces, as we have remarked before, no effect upon the periodic time of a revolution of the earth. It is now pretty well determined that the motion of the moon is continually accelerated. Upon comparing observations made at distant intervals, it is found that the Chaldean and Alexandrian observations give a longer period, than the Alexandrian and Arabian of the eighth century; and a comparison of the Arabian and modern observations, gives a still shorter period. These variations are all periodical, and are compensated in opposite points of every period, the mean distances, and mean periods, will always remain the same. "Cold, we think, must be the heart that is not affected by this mark of beneficent wisdom in the contriver of the magnificent fabric."

CHAPTER IX.

The Seasons.

"These, as they change, Almighty Father, these
Are but the varied God. The rolling year
Is full of thee." *Thompson.*

THROUGHOUT the preceding chapter, we have spoken of the plane of the orbit of the earth as inclined to the plane of the equator. As a necessary result of this, the axis of the earth points, at all times, towards the same point of the heavens, with the exception of the slight motion caused by the precession of the equinoxes. This is a fact, with which we are all familiar, for we know the pole star is the star towards which the axis of the earth points throughout the year. Thus, in the following diagram, let



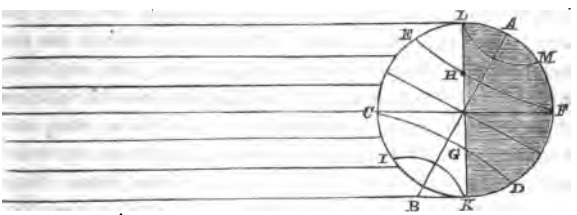
A B C D, represent the earth in four different positions in its orbit. Now, if the axis of the earth was perpendicular to the plane of the orbit, as shown in the diagram, then the plane of the equator, *a*, *b*, would correspond with the plane of the orbit, but, as the plane of the equator manifestly does not correspond with the plane of the ecliptic, the axis of the earth must be inclined to the plane of its orbit, as in the next diagram, and this inclination it maintains throughout its entire revolution around the sun, its axis always pointing towards the polar star. Of course, in our diagram, this does not appear to be strictly the case, as we cannot represent the star removed to a sufficient distance. The inclination of the axis of the earth to the plane of the sun's apparent path, is the cause of all the variety of the seasons; of the differing lengths of the nights and days; and the daily changes of the sun's declination. If the earth's axis had been placed perpendicular to the

plane of the ecliptic, then, at all seasons of the year, the days and

nights would have been equal all over the world, for, as will be seen on reference to the figure on page 105, the sun would shine from pole to pole, and as it would illuminate but half the globe at once, a spectator any where on its surface, would be just as long in passing through the unilluminated as the illuminated portion.

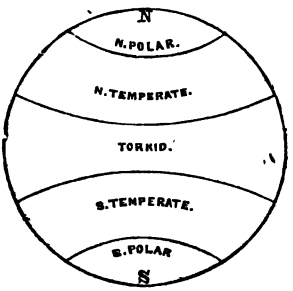
Thus, a spectator at A, on the parallel of latitude B C, would be just as long in moving through the half of the unilluminated portion of the earth B A, as through half the illuminated A C. This is the case at the equinoxes. When the sun is in either of those points of his orbit which crosses the equator, then it illuminates the globe from pole to pole, *i. e.* when he is in either of the points 0, or XII, see the figure on page 91. We have already shown that the apparent diurnal path of the sun through the heavens due to a rotation of the earth upon its axis, is in what is called a diurnal

circle, or a circle parallel to the equator; hence, at the time of the equinoxes, the sun will, apparently, in his diurnal circle in the heavens, move in the equator; and as the successive meridians come under, it will appear directly over head, or vertical, at noon, to a person any where on the equator. As the globe turns around, the sun now passes directly over the islands of Sumatra and Borneo, and the islands in the midst of the Pacific ocean; also over the northern part of South America, the middle of Africa, and the Indian ocean. We will suppose it is the time of the autumnal equinox, when the sun enters Libra, or is in the position marked XII, in the figure on page 91. A month after, the sun has moved to the position XIV. And as the earth turns around on its axis, it appears no longer vertical, or over head, at the equator, at noon, but to those places situated on the parallel *e f*, over the islands of New Guinea and Java; the middle of South Africa; the top of the Brazils; and, perhaps, the Society, and the Friendly islands. As the sun moves still farther on in its orbit, to the position VI, it appears now vertical, or over head, at noon, to an observer on the parallel *g h*, and as this is the greatest distance from the equator, and therefore farthest south where it can be vertical, at noon; and, as after this, it again approaches the equator, this point is called the solstitial point, *i. e.* the point where, having reached its greatest southern declination, the sun, apparently, for a few days, remains still, or at precisely the same altitude at noon, for a few days, and then begins to return; this limiting parallel on the earth is called the tropic of Capricorn, for it is now January, the time of the winter solstice, when the sun enters the sign Capricorn. The earth is now illuminated by the



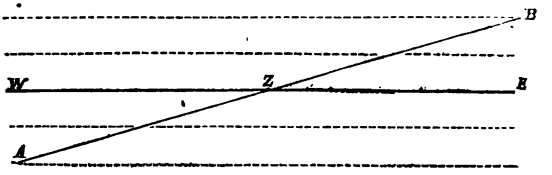
sun, as shown in this diagram. The sun being vertical at noon,

in summer, and also the days being longer than the nights, and the earth being thus warmed during the day more than it is cooled during the night, this excess of warmth contributes to augment the summer heat. It will also now appear why, although the earth is actually nearer the sun in winter than in the summer, no increase of heat is, on this account, perceived, as the rays, at this time, fall very slanting upon the earth in the northern hemisphere, although in the southern hemisphere, the summer occurring at the time when the sun is nearest the earth, is much warmer than the same season at the north. The lines we have thus seen, apparently marked on the earth by the sun, divide the earth into five zones, or belts. The north frigid; the north temperate; the tropical, or torrid; the south temperate; and the south



frigid. The first and last are included within the polar circles, and are always cold, inhospitable regions. The temperate zones are included within the polar circles and the tropics, whilst the tropical, or equatorial regions lie wholly within the two tropics. At the equator, as we have already intimated, and indeed for some distance north and south, nearly to the tropics, perpetual summer reigns, as the sun is, at almost all times vertical at noon; at the equinoxes, it is truly so; but at the time of the summer solstice, it is seen by the inhabitants of the equatorial regions passing between the zenith and the northern horizon, not, however, nearer the north pole, or the polar star, than the rest of the world perceive it; for to them, the north star is on the horizon. At the time of the winter solstice, it is seen by a spectator at the

equator, to pass between the zenith and the southern horizon, about as far from being vertical at noon there, as it is to us at the time of summer solstice. Hence, an observer there, looking directly overhead, might imagine the equator a line marked in the heavens extending from east to west, like the line E W; Z



being the zenith, or point directly overhead, and A B the sun's path, along which it would appear to move; being at Z, at the time of the equinoxes, rising directly east and setting directly west, and at B at the time of the summer solstice, describing, by the diurnal motion of the earth, the tropic Cancer, and at A at the time of winter solstice, its diurnal path being the tropic of Capricorn.

We have thus, at some length, explained the phenomena of the seasons, and will now, for a few moments, consider what will be the effect of the precession of the equinoxes. The earth's axis, at present, is inclined towards the sign Cancer, which is located in the constellation Gemini. In the course of about 6000 years, it will still be inclined towards the sign Cancer, but that sign will be in the constellation Pisces. And in 6000 years more, towards the constellation Sagittarius. In consequence of this change, the seasons will all, really, be misplaced about six months, although the various contrivances for retaining the names of the months, as indicative of the several seasons, will doubtless, then, as now, make the 21st of March the commencement of spring, or time of vernal equinox. There is, however, a more important change than this, which will affect our seasons The major axis of the earth, or line *a b*, see figure on page 78, has not a fixed direction in space, but is slowly moving from west to east, *i. e.* in the order of the signs, at such a rate that it will require about 100,000 years to make a complete revolution. The earth arrives at its perihelion

now about the 1st of January, but 50,000 years hence, it will be in its perihelion in July, or time of mid-summer in the northern hemisphere, and at that time the earth's axis will be inclined nearly as at present, unless changed by some great convulsion. The effect of this change of the direction of the line of apsides will be therefore, to cause the earth to arrive at its perihelion at the time of mid-summer in the northern hemisphere, instead of at mid-winter as at present, thus producing, if the relative distribution of land and water remains unchanged, a tropical climate or nearly so, over the whole globe.

Such periods of time are however, too remote to be worth much notice from us, except for their interest in a geological point of view, for we believe this to be the true explanation of the greater warmth of the climate of the ancient world, as indicated by fossil flora and fauna; we shall refer to this again.

We have given no explanation of the cause of the precession of the equinoxes, or the motion of the apsides. It would be extremely difficult for us to do so in a manner intelligible to the general reader. The facts, however, are unquestionable. The former is caused by the attractions of the sun and moon upon the excess of matter at the equator, for the earth is not truly spherical, but oblate, on account of its diurnal rotation. This equatorial belt, not corresponding with the plane of the ecliptic, is acted upon obliquely, and with varying force by the sun and moon, producing the retrogradation of the nodes. The motion of the apsides is the conjoint effect of the attractions of the planets upon the earth in the various parts of its orbit.

We here close the first part of our volume, not however, without the hope that we have succeeded in making it interesting, and that the reader will feel repaid for the time spent in perusing it.

THE WORLD.

PART II.

METEOROLOGY.

CHAPTER I.

Meteorology.

"'Tis pleasant, by the cheerful hearth, to hear
Of tempests, and the dangers of the deep,
And pause at times, and feel that we are safe;
Then listen to the perilous tale again,
And with an eager and suspended soul,
Woo terror to delight us." *Southey.*

We now enter upon that part of our subject which treats of the atmosphere, the waters of the globe, and the mountain rocks of which it is composed. No department of natural history abounds more in important facts and interesting conclusions. We commence first with "Meteorology."

The science of meteorology describes and explains the various phenomena which occur in the region of our atmosphere. The word is of Greek origin and means *aloft* or *elevated*. It is a study which has deeply engaged the attention of men in every stage of society, from the roving savage to the refined votary of wealth and pleasure. The moment we cross our thresholds we commit ourselves to the influence of the weather; but the hardier class of the community, the shepherd, the plowman, and the mariner, whose labor creates or procures the staple articles of life, are always exposed by their occupation to the mercy of the elements. They are hence led by the strongest motives, to examine closely

the varying appearance of the sky, and to distinguish certain minute alterations which usually precede the more important changes. Thus Virgil in one of the most beautiful passages of the Georgics gives for the use of the mariner and husbandman, the warnings which in his time were thought to precede approaching storms of wind, which he observes, well contemplating, the careful husbandman will gather his herds into their stalls; they are eleven in number. I. The agitation of the sea, the swelling waves rolling upon the shore. II. Noise from the mountains of the rustling leaves and crackling branches. III. The roaring of the surf as it breaks upon the shore. IV. The murmuring of the groves. V. The flight of sea-birds and their screams. VI. Their playing or sporting on the shore. VII. The herons forsaking their accustomed marshes and mounting aloft. VIII. The fall of meteors, portending winds, and which is thus similarly alluded to by Milton:

"Swift as a shooting star,
In Autumn thwarts the night, when vapors fired
Impress the air; and show the mariner
From what point of his compass to beware
Impetuous winds."

IX. Nocturnal streams of light, probably the Aurora. X. Straws rising and floating in the air. XI. The play of floating feathers driven about upon the surface of the pool. Next he gives twelve prognostics of rain, which were thought so conclusive in their indications that he observes "Never hath a shower hurt any person unforewarned," viz: thunder from the north; the clash of east and west winds, and the flight of the cranes into the vallies to avoid the impending tempests. Heifers snuffing the wind; the circling flight of swallows round the water, and skimming over its surface. The croaking of the frogs; ants busy with their eggs. The rainbow, which was then supposed to have drank the water that supplied the clouds. The hoarse murmur of the flocks of crows. The diving of sea birds and of swans; smoothing and oiling their plumage. A solitary bird pacing the sand; and lastly the gathering of fungous excrescence on the wick of the lamp, causing the oil to sputter and the flame to emit sparks. Prognostics of the coming weather drawn from the appearance of the

moon or sun, are also given. I. From the moon; darkened when new, she betokens rain. If red, wind; if serene in the fourth night she promises fair weather for that month. II. From the sun; if in rising, spotted, or showing only the centre of his orb, rain is portended. If of a bluish color in setting, rain, if red, wind. If spotted at setting, rain and wind; and if bright at rising and setting, clear weather with a northerly wind.

After these beautiful descriptions, which bring the poem home to every one, follow nine indications of fair weather. The brightnes of the stars, and of the rising moon. The unclouded sky, and kingfishers not expanding their wings to the sun; sows no longer tossing wisps of straws into the air. The clouds floating low; the silence of the owl at sunset, whose hooting was once supposed to forebode rain. The falcon soaring after the lark, and the crows social, and cawing with clear notes. Many of these signs are even now considered as harbingers of the coming change of weather, and more particularly the formation and arrangement of certain clouds, to which we shall again allude. No doubt the early observers of the weather often mistook the indications of those aspects we have mentioned, and inferred conclusions from mere casual circumstances.

The signs which usually precede the coming tempest are thus beautifully given by Thomson.—*(Winter, l.* 118, *et seq.)*

"When from the pallid sky the sun descends,
With many a spot, that o'er his glaring orb
Uncertain wanders, stain'd — red fiery streaks
Begin to flush around. The reeling clouds
Stagger with dizzy poise, as doubting yet
Which master to obey; while rising slow,
Blank, in the leaden-colored east, the moon
Wears a wan circle round her blunted horns.
Seen through the turbid, fluctuating air
The stars obtuse emit a shivering ray;
Or frequent seem to shoot athwart the gloom,
And long behind them trail the whitening blaze.
Snatch'd in short eddies, plays the wither'd leaf;
And on the flood the dancing feather floats.
With broaden'd nostrils to the sky upturn'd
The conscious heifer snuffs the stormy gale.
Even as the matron, at her nightly task,

With pensive labor draws the flaxen thread,
The wasted taper and the crackling flame
Foretell the blast. But chief the plumy race,
The tenants of the sky, its changes speak.
Retiring from the downs, where all day long
They pick'd their scanty fare, a blackening train
Of clamorous rooks thick-urge their weary flight,
And seek the closing shelter of the grove.
Assiduous, in his bower, the wailing owl
Plies his sad song. The cormorant on high
Wheels from the deep, and screams along the land.
Loud shrieks the soaring hern; and with wild wing

The circling sea-fowl cleave the flaky clouds.
Ocean, unequal press'd, with broken tide
And blind commotion heaves; while from the shore,
Eat into caverns by the restless wave,
And forest-rustling mountain, comes a voice,
That solemn-sounding bids the world prepare.
Then issues forth the storm with sudden burst,
And hurls the whole precipitated air
Down in a torrent."

Those tokens which portend the more violent convulsions of the atmosphere, the pelting storm, or the careering tempest, are generally of a decided character, but the symptoms which go before the ordinary fluctuations of the weather can only be dimly conjectured by long experience and sagacious observation.

Nothing can be more utterly groundless than the disposition to refer the ordinary changes of the weather to the influence of the moon. But, compared with this, the fancied efficacy of the stellar aspects vanishes into the shadow of a vision. The moon by

its attraction does raise a small tidal wave in the atmosphere, which is indicated by the barometer, but its effect is scarcely perceptible. According to the calculations of Laplace, the joint action of the sun and moon is only capable of producing a tropical wind flowing westward at the rate of about four miles a day, and the effect produced by the conjoint actions of Jupiter and Venus, when nearest the earth, would be a very gentle breeze moving about a foot in fourteen or fifteen days, or about a mile in twenty years.

The invisible and perfectly elastic fluid which surrounds the earth is called the atmosphere, or atmospheric air. It appears to consist principally of two distinct expansible fluids, mechanically combined in different proportions; a single portion or atom of oxygen gas being united to three parts by weight, or four by bulk of nitrogen, with a very slight admixture of carbonic acid, perhaps one-thousandth part of the whole. Air was formerly considered as an elementary body, but the analysis of this rare medium is one of the finest discoveries of chemistry. The atmosphere, although apparently so rare and mobile, is nevertheless, capable of presenting great resistance to any obstacles to which it may be opposed. We shall see this more completely illustrated when we describe the phenomena attending hurricanes and other windy storms, but meanwhile it will answer our present purpose to simply refer to its use as a natural agent in propelling vessels by means of sails, and urging the sails of wind mills. Although it is, comparatively speaking, light, and in the ordinary acceptation without weight, yet we must not forget that it is now clearly demonstratable that the atmosphere which invests our earth, presses everywhere on its surface with a power of about 15 lbs. to the square inch. The famous Torricellian experiment proves this. It is well known that if the mouth is applied at one end of a small tube, the other end of which is immersed in water, that upon exhausting the air from the tube by the process called suction, the fluid rises swiftly and flows into the mouth; this is a philosophical experiment, but well known to every child. Now, if a person ignorant of the principle that caused the water to rise in the tube, should be asked for an explanation, he might answer

as Galileo did, that it was "Nature's abhorrence of a vacuum." It is however, effected by the pressure of the atmosphere. When an open tube is dipped at one end into the water, the liquid does not rise in the tube until the air within it is removed by exhaustion, as we have described, when immediately the fluid rises, because the atmosphere without the tube, pressing upon the mobile particles of the fluid, forces them up. Now it is evident that if the tube was long enough, and the exhaustion perfect, the pressure of the air upon the liquid outside would raise a column of water just so high that the weight of this elevated water would be equal to the pressure of the atmosphere upon the liquid at the bore or orifice of the tube. The column of water which can be thus raised or sustained, is generally about 33 feet high; and as such a column when its area is one square inch, weighs about 15 pounds, we infer that the atmosphere presses upon the earth with a force of about 15 pounds to the square inch. Mercury or quicksilver, being 14 times heavier than water, the atmosphere will support a column of this but about 29 or 30 inches in height; and when a tube a little more than 30 inches long is closed at one end, and filled with mercury, and then inverted into a basin also containing mercury, the column will remain suspended nearly thirty inches high. The mercurial column would continually remain at the same elevation, if the atmosphere was subject to no variations; but this is not the case; upon observation it is found subject to continual variation, almost always falling before a wind arises, and preceding rain, and again rising at the approach of calm and fair weather. The instrument thus becomes a *barometer*, or measurer of of the weight of the air. It is an invaluable instrument on ship-board, giving indications of the coming tempest long before any change is detected in the appearance of the sky.

Since the barometric column is wholly supported by the pressure of the atmosphere, communicated through the mobile particles of the fluid metal, to the open mouth of the tube, it obviously points out a method of determining heights. This however, is from several causes, a matter of some nicety; thus the density of the air decreases as we rise upward, owing to the extreme elasticity of air. It is well known that a piston may be thrust

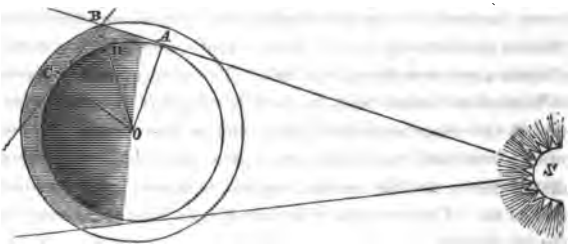
down a tube closed at one end, condensing the air before it, until it can absolutely be urged no farther, the included air resisting its descent as effectually as any metal; upon releasing the pressure it again expands to its original bulk. The stratum of atmosphere in immediate contact with the earth is subject to the entire pressure of the superincumbent mass, and is thus denser, *i. e.* has more atoms contained in the same space than the stratum immediately above, and the second stratum is denser than the third, and so on. This decrease of density gives a limit to the extent of the atmosphere.

The ancients imagined that our atmosphere reached at least as far as the moon, but the discovery of the weight and pressure of the air destroyed at once this magnificent vision. Comparing the length of the mercurial column with the density of the aerial medium, it follows that if the atmosphere is a uniform fluid, it cannot exceed the elevation of five miles. But the air being very dilatable, the higher portions sustaining as we have shown a diminished pressure, must swell upwards and occupy a proportionally greater space. This property removes the boundary of the atmosphere to a much greater elevation. A height of 42 miles would indicate a rarefaction of a thousand times, for it has been proved that the density decreases in a geometrical ratio, as the height increases in an arithmetical ratio, thus:

The elevation being in miles,.....	0	3	6	9	12	15	&c.
The density will be,.....	1	½	¼	⅛	1-16	1-32	&c.

The famous Kepler first proposed a method of determining the height of the atmosphere by means of the twilight. After sunset there appears in the western sky a bright illumination called twilight, which is caused by the sun's rays shining upon the higher regions of the air. This twilight fades when the sun has sunk below the horizon a certain distance; thus, let C be the position of a spectator upon the earth, encompassed with its atmosphere, and S A B the lowest ray of the sun after sunset, B C being the horizon. The sun's rays would now illluminate the portion of atmosphere between A and B, producing twilight visible to a spectator at D, but not to one at C. Now the twilight, or this last ray

of twilight, S A B, expires whenever the arc D C, is equal to 9°,

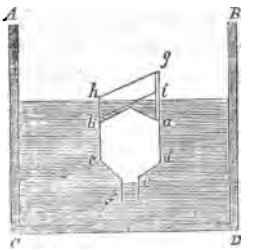


or one-fortieth of the whole circle. The angle B C O is evidently a right angle, or 90°, consequently, from the well known principle that the square of the longest side of any right angled triangle, as B O C, is equal to the sum of the squares of the other two sides; the square of B O, is equal to the square of O C, added to the square of B C. Now B O is the height of the atmosphere, added to the half diameter of the earth, and O C is also the semi-diameter of the earth, or 4000 miles nearly, whilst B C, which may be assumed equal to D C, is the one-fortieth of the circumference of the earth, or 600 miles nearly. Hence the square of B O is equal to 600^2, plus 4000^2, which is 16,360,000, and the square root of this is 4045, which is the length of B O; subtracting D O, or 4000 miles, leaves 45 miles for B D, the height of the atmosphere. It is probable the atmosphere extends beyond this, as, unless the sky be overcast, there is total darkness in no climate, even at midnight, and therefore the atmosphere must extend to such a distance as to receive the most dilute glimmer after the sun has attained his greatest obliquity, and sunk 90° below the horizon; this would require an elevation of at least 1640 miles, and before the centrifugal force would balance the attraction of gravitation, it is possible it might extend 22,000 miles, and yet, this is scarcely a twentieth part of the distance of the moon. If the atmosphere really spreads out, even to the first mentioned limit, it must, in its remote verge, attain a degree of tenuity which it would baffle the imagination to conceive.

It was soon conceived, after the discovery of the pressure of the air, that the height of the mercurial column would vary with

the elevation at which it was observed. The experiment was tried by M. Perier, at the suggestion of his brother-in-law the celebrated Pascal, who himself living at Paris, was not so conveniently situated as M. Perier, who lived at Clermont, in Auvergne, in the immediate vicinity of several mountains, which modern geology proves to have once been active volcanoes. Early in the morning of the 19th of September 1648, (two hundred years ago) Perier with a few friends, assembled in the garden of a Monastery situated near the lowest part of the city of Clermont, where he had brought a quantity of mercury, and two glass tubes closely sealed at the top. He filled and watched them as usual, and found the mercury to stand in both tubes at the same height, namely 28 English inches; leaving one behind in the custody of the sub-prior, he proceeded with the other to the summit of the mountain, the Puy de Dome, and repeated the experiment. Here the party were delighted, perhaps we may say surprised, although they expected it, to see the mercury sink more than three inches under the former mark, and remain suspended at a height of only 24.7 inches. In his descent from the mountain he observed at two several stations, that the mercury successively rose, and returning to the monastery it stood at exactly the same point as at first, thus incontrovertably proving that it was the pressure of the atmosphere which balanced the suspended column.

We will close this chapter with a description of a barometer or baroscope, which any one who has access to a tin-shop can



construct, it is an instrument of great delicacy in its indications. Let A B C D, be a vessel partly filled with water, in which the

hollow air-tight body *a b c d* is floating, having a tube, *e f*, opening into the interior. When placed into the water it is evident that a certain portion of the liquid will rise in the tube, and if light weights are added either below or above, the whole body may be caused to sink until its top is even with the surface of the fluid; *a g* is likewise a tube, which containing air, will prevent the instrument in great changes of weather from sinking to the bottom, *b h*, is a wire, and *g h* and *i b* are threads stretched obliquely from the tube to the wire. As the instrument rises and falls, a little bubble of air on the thread shows the motion; the threads are so located that when the bubble reaches *i* on the lower, it commences at *h* on the upper one. A change of the pressure of the atmosphere preceding a wind or rain, by reason of a diminished pressure upon the surface of the water in the vessel, A B C D, forces less of the fluid into the tube *e f*, and thus the specific gravity of the included air being lessened by its expansion, the instrument rises, and the bubble descends, corresponding with the fall of the mercury in the barometer. When, on the approach of fine weather, the atmosphere becomes calm, and of its usual density and elevation, the water being forced into the tube *e f*, by the increased pressure causes the baroscope to sink, and consequently the bubble to rise. It is said that this instrument will show alterations in the air 1200 times more accurately than the common barometer. The inventor, Mr. Caswell of Oxford, observes that the bubble is seldom known to stand still even for a minute; that a small blast of wind that cannot be heard in a chamber will sensibly make it sink, and that a cloud passing over it always makes it descend. The greatest objection to this very simple instrument is, it is liable to be affected by the expansion of the included air by heat.

CHAPTER II.

Winds.

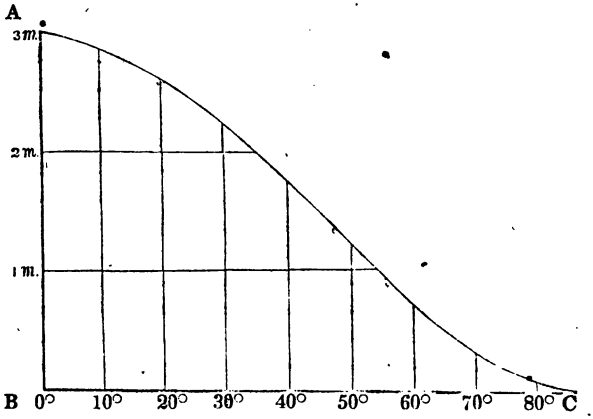
"He spoke, and, at his call, a mighty Wind,
Not like the fitful blast, with fury blind,
But deep, majestic, in its destined course,
Sprung with unerring, unrelenting force,
From the bright East. Tides duly ebbed and flowed;
Stars rose and set; and new horizons glowed;
Yet still it blew." *Rogers.*

In the preceding chapter we have alluded to the weight and decreasing density of the air. In the present we shall consider it in its relations to heat and moisture, in which connection it performs a most important part in the economy of nature. Air, like all material bodies, expands when heated, and thus its specific gravity being lessened, it rises. Every one is familiar with this fact. The little whirligigs placed on stoves, are turned by the ascent of the heated air, and the draft of chimneys and pipes depends upon the same principle. We might infer that if air expands upon being heated, it will part with this heat on being condensed. This is the fact, upon forcing a close fitting piston down a tight tube, suddenly compressing the air before it, a heat is evolved, sufficient to inflame good tinder. We well remember in our younger days performing this feat, using a leaden tube for the pipe, and a bit of wood with a circular and greased leather nailed to one end, for a piston, placing the "punk" in the folds of the leather.

The ascent of heated air from the earth is one of those silent and often unobserved agencies employed to produce a general equilibrium in the temperature and moisture of the earth. The air itself being transparent, is scarcely heated by the passage of the suns rays, but the stratum nearest the earth absorbing a portion of the heat, rises and gives place to a colder portion, which in its turn is displaced by another, and thus the excessive heat which, in some portions of our globe, would parch up the earth and destroy all life, is rapidly carried off, and a more genial tem-

perature produced. The heated portions of air distribute their warmth throughout the great body of the atmosphere, and sometimes in the form of winds sweeping over colder regions of the earth, moderate the rigor of the climate.

Ascending from the earth we find the temperature of the air constantly diminishes until we arrive at a region of frost, the limit of which, is called the *term of perpetual congelation*. The height of the term of congelation varies for every change of latitude. In the following diagram taking A B, for the height of



perpetual congelation at the equator, and B C, for the line of latitudes, then the decrease in the height of the term of congelation from the equator to the poles, may be represented by the several parallels bounded by the curved line A C. The region of perpetual frost at the equator is at a height of 3 miles, at a distance of 35° from the equator, about 2 miles, at 54° about 1 mile, at 80° very near the surface of the earth, and at 90° the surface of the earth. It will be well to fix in the mind, the limits here assigned, as we shall often refer to this varying elevation in explaining the phenomena of rain, hail and snow. The clouds almost always float below the term of congelation.

Although the temperature of the surrounding atmosphere is

generally colder as we ascend, yet from local circumstances the heat of the earth being increased, the air becomes sometimes very mild even in elevated districts. Valleys, it is well known, are warmer than level plains in the same latitude on account of the reflection of the sun's heat from neighboring hills and mountains. In Switzerland, instances occur of spots of verdure in the midst of perpetual snow and glaciers. We give below a view of the glacier of Grindelwald in the Canton of Berne. Here woods and meadows border close upon the immense fields of ice, which

descending from the upper regions, cover an extent of about 1200 square miles of territory. The ice is seen presenting innumerable peaks in the gorge between the mountains. It is said that there are plains in the Himalayah mountains 15,000 feet above the level of the sea which produce fine pasturages.

Air when put in motion produces what is called wind, and the variable distribution of heat throughout the atmosphere is the main cause of wind, or flow of the air, for thus the local density is constantly affected, and the equilibrium of the mass disturbed. Winds are exhibited in various forms, breezes, high winds, gales, hurricanes and tornadoes. These varieties depend chiefly upon their different velocities, a velocity of twelve miles an hour making a strong breeze; sixty miles, a high wind; one hundred miles a hurricane.

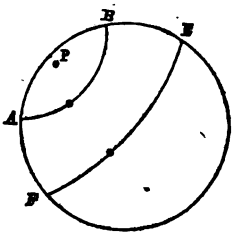
The force of the wind when moving with the velocity of a hurricane or tornado, is almost incredible; when we speak of the geological changes that have passed over the face of our globe

during its past existence, we shall have occasion to refer to their agency; no power can resist the combined action of winds and waves. Hurricanes and high winds are generally characterized by a whirling motion producing the phenomena called whirlwinds, these often exhibit the most incredible power, uprooting huge trees, and whirling their dismembered fragments into the air, unroofing houses, and even raising aloft animals, and heavy carts. The great gales of the ocean manifestly exhibit more or less of this rotary motion. Such are the the hurricanes which annually sweep over the Indian seas and along the Atlantic coast.

Our limits will not permit us to be very extended upon this subject, and we shall therefore briefly notice some of the more peculiar winds, and we commence with the land and sea breezes. These are occasionally met with in every latitude, but are constantly observed near the shores of the continent, and of the larger islands within the tropics. In these sultry regions, as the day advances, a refreshing wind blows from the sea, and is succeeded by an opposite current from the interior of the land on the approach of evening. The cause of these diurnal winds is obvious. The change of temperature between the night and day on land often varies more than 40° or 50° Fahr., while at the same time on the water it seldom varies more than 1° or 2°. The large body of heated air over the land, rising continually during the day, a denser and colder portion rushes in from over the water to supply its place, causing the sea breeze. During the night the ground cools much more rapidly than the water, and the lower stratum of atmosphere thus soon becomes colder than at sea, consequently a stream of air thus flows toward the sea, displacing the lighter and warmer air, producing the land breeze. This breeze is never as powerful as the sea breeze, but is much colder. Every one who is familiar with these breezes must have noticed the period of peculiar languor and depression, between the change from the sea to the land breeze.

Dr. Robinson mentions an experiment which illustrates the cause of land and sea breezes very prettily. If we place a hot stone in a room, and hold near it a candle just extinguished, we will see the smoke move toward the stone, and then ascend up

from it, precisely similar to the movement of the air, heated by contact with the land, and perhaps the sloping sides of mountains. The most remarkable aerial currents, and of the greatest importance in navigation, are the trade winds, which, within the tropics, blow continually from the east, though with variable force, and declining north and south, according to the latitude, and season of the year. The primary cause of the trade winds is analagous to that of the land and sea breezes, though much more extensive, and maintaining a constant direction, and likewise united with the influence of another cause, viz: the rotation of the earth. We have already had occasion to remark that within the two tropics lies a belt, over some part of which the sun is vertical at noon, at all seasons of the year, hence this equatorial belt, in the torrid zone, is continually heated by the sun, and a large body of air warmed by contact with the heated ground, rises constantly to the upper regions. Its place is supplied by colder air moving along the surface of the earth, from the colder northern and southern climates. The effect of this would be to produce a north wind north of the equator, and a south wind south of the equator. The portion of air thus transferred from the higher latitudes to the equator has a slower diurnal motion than at the equatorial regions. Perhaps a diagram will make this more plain.



Let P be one of the poles of the earth, A B a parallel of latitude, and E E, the equator. Now it is evident that the diurnal movement of a body attached to the parallel A B, is slower than one at the equator E E, since the equatorial belt or circle, is of much greater circumference than the circle of latitude, and both are

moved over in the same time. If therefore, a body, still retaining the quantity of motion it had while upon A B, should suddenly be placed upon E E, it is evident that the excess of motion at E E would leave it behind. This is actually the case with the colder air rushing from the higher latitudes to fill the space vacated by the ascent of heated air within the tropics. The air thus transferred, does not acquire at once the motion of the equatorial regions, and consequently lags behind, or the earth moves under it, and thus since the earth moves from west to east upon its axis, it gives the appearance of a wind coming from the opposite quarter, *i. e.* from the eastward. But, as we have seen before, these winds had a direction from the north, at all places north of the equator, and from the south, at all places south of the equator, combining the two therefore, we will have a constant north-east wind one side of the equator, and south-east the other; these two winds, meeting at the equator, will flow constantly eastward, or destroy each other and produce a calm. Such is the character of that general wind, which encircles the globe, flowing with slight deviations, constantly from the east, and spreading over a zone of more than 50° in breadth. It sweeps the Atlantic ocean from the coast of Africa to Brazil, and the Pacific from Panama to the Phillipine islands, and New Holland; and again over the Indian sea partially, from Summatra to Zanguebar; here however its direction is curiously varied, owing to the peculiar locality of this ocean.

The course of the trade winds is changed or interrupted by high lands, thus calms and variable winds prevail at the Cape Verd islands, being under the the lee of the African shore, and an eddy, or counter current of air from the south-west, is generated under the coast of Guinea. The lofty barrier of the Andes shelters the sea on the Peruvian shores from the trade winds, which are not felt until a ship has sailed eighty leagues westward, but the intervening space is occupied by a wind from the south. The heated air of the tropics after becoming somewhat cooler in its passage towards the temperate regions, descends to the earth still retaining in a great measure, its equatorial velocity, consequently, it sweeps over the surface of the earth in the same di-

rection in which it is turning, but somewhat faster; this gives the appearance of a westerly wind of considerable force and regularity. According to Robbins, a westerly wind almost constantly prevails in about latitude 60° S. in the Pacific ocean. In Hudson's Bay, westerly winds prevail three-fourths of the year, as also in Kamschatka. Still farther north, as at Melville island, the north, and north-west winds prevail. On account of these winds, the Atlantic may be crossed eastward in about half the time of returning westward. The existence of the upper current of the trade winds was shown in a striking manner at the eruptions of the volcano in the island of St. Vincent in 1812. The trade winds blow with great force from Barbadoes to St. Vincent, but ashes erupted by the volcano fell in profusion from a great height upon Barbadoes, which is about 150 miles westward. Since the westerly winds which prevail in the higher latitudes are caused by bodies of air from the torrid zone, which often descend to the earth before the heat is quite gone, such winds are generally warm, and on the same principle winds which blow directly from the arctic pole, are intensely cold, and, as they must appear from the rotation of the earth, to come from the north-east, our easterly and north-easterly winds are always severely cold.

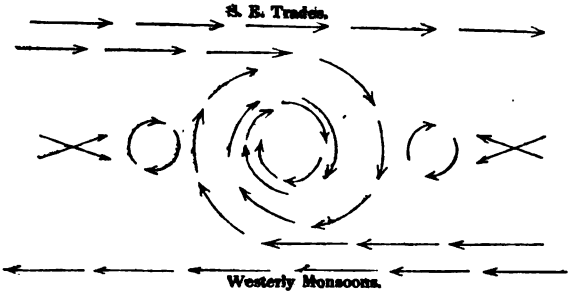
We will now consider the causes which result in changing the direction of the trade winds in the Indian ocean, producing what are termed the monsoons. When it is summer in the northern hemisphere the great body of land above the Indian ocean becoming more heated than the sea, a breeze sets towards the land, which, modified by the rotation of the earth, gives a strong south-east wind. On the contrary, when it is winter in the northern latitudes, the great body of water, as also the vast island of New Holland, becoming more heated than the continent farther north, a wind sweeps over the Indian and southern oceans, whose general direction is south-west; this wind not being opposed in direction to the rotation of the earth, is more powerful than the other. The interval which separates the monsoons is variable, but occurs generally near the equinoxes, during this interval, violent gales occur called Typhoons.

According to Mr. Redfield, who has most ably and successfully

investigated the phenomena of the great storms which traverse the Atlantic coast, they may be traced to the N. E. of the West India islands, and are from thence, drifted to the westward on a track which inclines generally to the northward and eastward. The rate of progression varies from 12 to 30 miles per hour, and the storm whirls or blows from right to left, in a horizontal circuit, on a vertical and some what inclined axis of rotation which is carried forward by the storm. Mr. Espy has proposed a theory which to us appears at variance with the facts derived from general observation, and independent of any hypothesis. According to this doctrine, it is alleged that during hurricanes, the wind, instead of blowing in a circle, rushes directly from the exterior towards the centre, to supply a vertical current under influence of the suction, or vacuum power caused by the rarefaction and ascent of air, consequent from the extrication of the latent heat of vapor during condensation. This theory has been ably defended by Dr. Hare. The rotary theory of storms is now pretty generally acknowledged, and has been advocated by Mr. Redfield, Sir John Herschel, Lieut. Col. Reid, Prof. Dove of Prussia, and Mr. Alex. Thom. The latter gentleman has published a book on the nature and course of storms, in which, he traces the origin, and describes the phenomena, of the great hurricanes annually occurring in the Indian ocean, showing them to be vast circuits of wind, revolving in a particular direction with unerring regularity; that they move from about latitude 10° S. by a south-westerly track, curving towards the tropic. Their diurnal rate of progression diminishes as they recede from the equator. These hurricanes are formed by the westerly monsoons, and the S. E. trade winds; the following diagram is extracted from Mr. Thoms' work, and will illustrate the manner in which these storms are generated.

When the hurricanes are first noticed they are from 400 to 500 and even 600 miles in extent, or diameter, and consequently, as the space between the monsoons and the trades is seldom more than 100 miles, the outer portions of the circle must be involved in the two winds for the space of two hundred miles on each side. Each wind therefore communicates a part, if not the

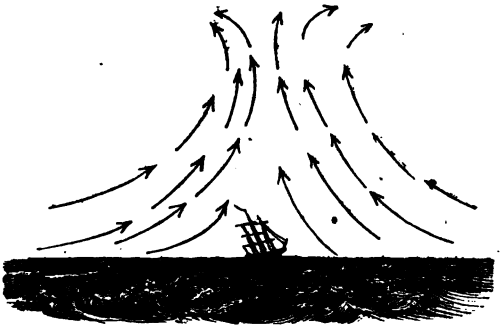
whole of its motion, in a tangential direction, and by their reverse directions produce a uniform circular motion. If the south-east



trade impinges upon one side at the rate of 30 miles per hour, and the monsoon at the same velocity on the other, the amount, converted into a rotary motion, would be equal to 60 miles at the exterior. The stormy revolution appears to extend to a great height, passing over the lofty mountains of the Isle of Bourbon and the Mauritius without being destroyed, though these arrest the trade winds. The same cause which produces the gyratory motion carries the storm forward.

The awful phenomena developed during a hurricane, depend upon the sudden reductions of the masses of air involved in it, of different temperatures, to the same standard, producing the most terrific exhibitions of thunder and lightning, attended with rain, hail &c. The trade winds are cool, but the monsoons are hot and humid. In most hurricanes, the fall of the mercurial column is equal to 1 inch, or even 2 inches, and the velocity of the wind just entering the focus as great as 150 miles an hour. In the focus of a rotary storm the horizontal direction of the wind suddenly ceases, and often, the storm appears, to one ignorant of its nature, to have passed off, when suddenly it commences again with the utmost fury, and at a point of the compass opposite to where it left off. This fact is strikingly noticeable even in the small hurricanes which in the autumn and spring, blow over our western lakes, and we have several times witnessed a violent hail and thunder storm, during which the wind raged with the

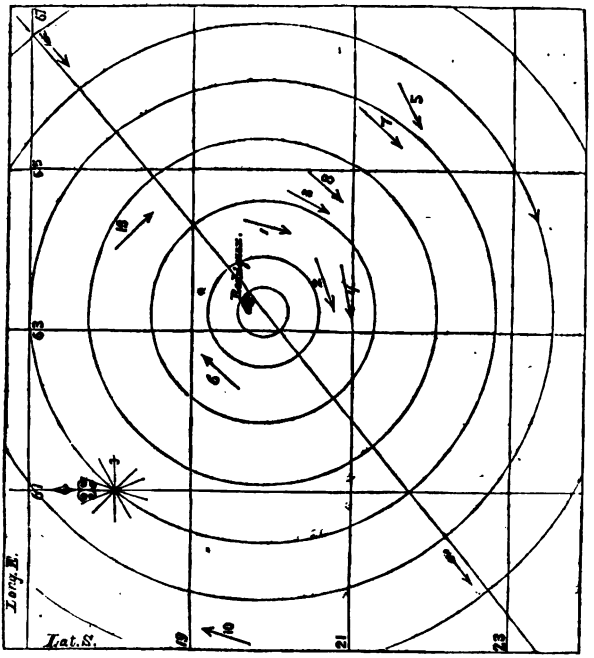
utmost fury, to apparently return with the wind in quite the opposite direction, after an interval of 15 or 20 minutes of perfect calm. The cause of these calms and the course of the air in the focus of a circular storm, is represented in the diagram.



We have scarcely room to add a description of the famous Rodriguez hurricane of April 1843. Such a fleet of wrecks from one storm never was seen before, having 14 or 15 vessels entangled its stormy circuit, some on its skirts, others crossing its path and following its wake, some rushing into the very focus and scudding around the vortex till rendered perfectly unmanageable by the fury of the sea and wind; its course could be tracked for 1500 miles, demonstrating beyond a doubt, that it was a vast whirlwind. We give a diagram of its position on the 4th of April, when its centre had just passed over the island of Rodriguez. The arrows represent the positions of the vessels and the direction of the wind, as gathered from the log-books. Though some of these vessels were but a few hundred miles from each other, yet they had the wind from opposite quarters.

Besides the winds which we have mentioned we may enumerate among local winds, or winds which affect only particular sections of country, the Sirrocco, a hot wind, moist and relaxing, which visits Naples and the south of Italy, blowing from the opposite shores of the Mediteranean. This wind is very unhealthy; during its continuance all nature seems to languish, the vegetation droops and dies, and the animal spirits are too much exhausted to per-

mit any exertion. The Harmattan is a cold dry wind of very



parching quality, frequent in Africa; it is a periodical wind of uncertain continuance, and is attended by a thick fog or haze, which either wholly obscures the sun or makes it appear a faint red easily borne by the eye. It is so dry that the eyes, lips, palate &c., are parched and painful, causing the skin to shrink and crack, and sometimes to peel off. It is however considered as an effectual cure for some diseases. The Samiel or Simoon, is a burning, pestilential blast, extremely arid, which springs up at times in the vast deserts of Africa, and rushes with tremendous fury, involving whole pillars of sand. It produces instantaneous death, and mortifies the body so effectually, that the limbs may be separated without difficulty. The camels seem to have an almost instinctive

notice of its approach, and are so well aware of the noxious qualities arising from its extreme dryness, that they bury their noses in the sand to avoid breathing it. So impetuous is this wind that its fury is past in a few moments.

We have now briefly described the more prominent winds which blow over the surface of our globe. We shall, when considering the changes which have modified, or entirely altered the face of the various continents and islands, which at present, form the "dry land" of our planet, perceive that they have acted a most important part. No force can resist the perpetual assault of the winds and waves. The sea, lashed into fury by the careering tempest, forces its way through barriers of porphyry and granite, undermines the rocky cliffs, and piles immense dunes or sand-hills along the low shores. Beneath the fine sands of the boundless eastern deserts, the monuments of ancient Egypt, her statues and sculptured temples, have lain hidden for ages, but the dry impalpable powder has fallen harmless upon them, and now, when the curious traveler from the western world, from lands unknown to the hierophants, uncovers with careful hands the buried tombs of kings, he beholds the color glowing upon the walls as bright, and perfect, as when first laid on by the Egyptian artist 3000 years ago; and the winged globe and heads of Isis as sharply outlined as though chiseled but yesterday.

CHAPTER III.

Formation of Clouds and Dew.

"The clouds consign their treasures to the fields,
And, softly shaking on the dimpled pool
Prelusive drops, let all their moisture flow
In large effusion o'er the freshen'd world."

Thomson.

THE relations of the atmosphere to water are very important and numerous. The various winds as they sweep over large tracts of country, or the ocean, become charged with moisture, which they bear with them to the higher regions, to be there employed in the formation of clouds, or rain. The formation and dissolution of clouds, produces all the varied train of meteorological phenomena. The humidity suspended in the atmosphere is derived by exhalation partly from the land, but ultimately from the vast expanse of the ocean. The moisture, deposited by the air is in the form of minute globules, which remain suspended, or subside slowly, constituting a *cloud*. When it comes near us, whether it hovers on the tops of the hills, or spreads over the valleys, it receives the name of a *fog;* when deposited from the air in a clear night, upon the surface of the ground, or bodies exposed to the air, it is called *dew*.

In order to explain more clearly the formation of clouds and also the deposition of dew, let us consider in what manner the capacity of air for moisture will be affected either by heat or cold. By capacity, we mean power of stowing away so as to render invisible. As a general rule, we find the capacity of air for moisture increased by heating, and dimished by cooling, it being capable of taking up and holding in an invisible state, a greater quantity of water when heated, than it can retain when cooled. Although the capacity of air for moisture is increased by heating, yet it is not proportional to the heat, but increases in a faster ratio.

For instance, an increase of temperature 10°, of air already heated to 70°, will increase its capacity for water much more than the same increase to air heated to only 40°. The converse of this is also true, the cooling of hot air diminishes its capacity for heat, much faster than the cooling of air already cold. Air in mounting upwards becomes colder, and since every increase of cold is attended with a dimunition of capacity for moisture, it becomes proportionally damper, and thus the middle regions of the atmosphere become soon charged with moisture, and were it not for a conservative principle which we will now mention, the heavens would be perpetually shrouded with clouds; this principle is, air in expanding has its capacity for moisture increased, and therefore, as the air which is ascending, continually expands from the dimunition of pressure, it becomes consequently drier and drier.

Clouds are formed either by a watery vapor rising so high as to reach a degree of cold sufficient to condense it, or from a mixture of warm air with cold, the moisture being derived from the warmer portion. Fog is nothing more than a cloud formed upon, or near to, the surface of the earth, and is due to a mixture of warm and cold air. Thus in a cold morning we see moisture deposited from the warm breath of animals, when it comes in contact with the air. The course of that remarkable body of water which is called the Gulf Stream, and which flows in a warm current from the Gulf of Mexico as far up as the banks of Newfoundland, is marked by a fog, produced by the colder air sweeping over it. Fogs are not common in hot climates, the air being too warm near the surface of the earth to condense the moisture sufficiently to form a cloud.

Dew is formed when air charged with moisture comes in contact with a surface in a certain degree colder than itself. The formation of dew may be very prettily illustrated by bringing a tumbler of cold water into a warm room, the outside of the tumbler will soon be covered with a coat of moisture, deposited from the warm air which has come in contact with it. In order to have a copious deposite of dew it is essential that the ground should be considerably colder than the air above it, and, it is actually found, that upon those nights when the most copious dews

occur, the ground becomes 12 or 15° colder than the air a few feet above it. Dew is deposited very unequally upon various substances; plants and vegetables, which need this sustenance, receiving the greatest abundance; but little is deposited upon the dry land, still less upon polished metalic bodies, and none at all upon the ocean. The deposition in these cases is proportional to the temperature, some bodies growing much colder than others when exposed to the same cooling influence; the surface of the ocean, as we have before remarked, remains at nearly the same temperature as the air incumbent upon it.

The surface of the earth is cooled by radiation of the heat it has received during the day, and thus prepared for the deposition of the dew. Hence dews are most abundant in a clear night when the heat radiated from the earth is not intercepted and thrown back from overhanging clouds. It is from this circumstance that the vulgar notion arises that the rays of the moon have a chilling influence. When the ground becomes cooled by the radiation of heat from its surface, below 32°, the dew is frozen, and then takes the name of *white* or *hoar frost*.

It will be apparent from what we have said, that dew will occur most frequently when there is a considerable difference between the heat of the day and the night. It is on this account that we seldom have dews either in mid-winter, or mid-summer, *i. e.* at the solstices, but generally just after the vernal, and before the autumnal equinox, viz: in May, and August. Dew is most copious in those places which are sheltered from the wind, and high winds therefore are a sure preventive to its formation, and of hoar frost. Dew and frost occur most frequently in clear weather, when the radiations of heat from the ground are thrown up into the sky without being again reflected, hence the thinnest screen, or the shade of a tree is a protection, and a cloth thrown over delicate plants will preserve them from frost. The quantity of moisture precipitated from the atmosphere, depends upon a variety of circumstances; on the previous dampness of the commingled portions of the fluid, their difference of heat, the elevation of their mean temperature, and the extent of the combination which takes place. When the deposition is slow the very

minute, aqueous globules remain suspended. These are found to be made up of hollow vesicles, filled with air like a soap bubble; and as the air included, is rarefied by the latent heat when the vapor is condensed, the weight of these vesicles becomes less than the weight of an equal bulk of air, and therefore they rise or float, forming a cloud. When the air within these vesicles bursts, the drops of rain are formed, which are changed, according to the circumstances attending their formation, as regards rapidity and copiousness, or the state of the medium as to heat, into hail or snow. In order for the precipitation of moisture necessary to form rain, hail, or snow, contending currents must bring vast fields of air of different temperatures over a given spot, as for example, when a warm south-east wind encounters a cold north-wester. In some parts of the world, as in Egypt, part of Chili, and Peru, it seldom rains, for there the winds usually blow in one direction.

Snow is formed by the crystalization of aqueous vapor instead of its formation into drops. It is thus converted into a white downy substance, which falls gently to the surface, forming in winter a warm covering, confining effectually the heat of the earth. The snow huts of the natives of Labrador are said to be quite warm. Below are figured some of the beautiful forms which the snow crystals assume in cold climates,

Hail is formed by drops of rain suddenly congealed during their fall, by passing through a lower stratum of dry and cold air. The

most violent hail storms are caused by a sudden transference of a body of warm air up beyond the term of perpetual congelation, where the drops of rain are frozen into hail stones. This is sometimes accomplished by means of whirlwinds, by which the hail-stones being sustained for some time, are occasionally accumulated to a very large size. By referring to our figure of the curve of perpetual congelation, page 126, it will be understood why hail storms seldom occur in the equatorial regions, and most frequently in the temperate zones, and seldom or never in the polar regions. The term of congelation is too high at the equator for the hot air raised by a whirlwind to pass beyond, or up to it, and at the polar regions, the air seldom becomes as hot as is required to form hail storms. Different names have been given to the various forms of clouds, derived from their appearance and character, we will briefly notice them. First, we have, occurring at the greatest elevation, the *Cirrus*, or curl-cloud, which is a thin fleecy vapor, with a waving and striated appearance as shown in the engraving below. This cloud is frequently called the curl-cloud

from its flexuous form, and is not unlike a bunch of wool pulled out into fine pointed ends. After a continuance of fine weather the cirrus is often observed at great heights like a fine white line stretching across the sky. The peculiar form of cirrus shown in

the engraving, called vulgarly, mare's tail, is thought to be an indication of violent winds, and the wind is generally from the quarter towards which the fine extended ends are pointed. When carefully observed, every particle of the cirrus cloud seems to be in motion, though the whole cloud appears nearly stationary. This cloud under different circumstances, presents considerable variety of appearance. After a continuance of clear and fine weather a whitish line of vapor stretched out like a thread, may be observed at a very great height, the ends seeming lost in the horizon, this is often the first indication of a change from dry to wet weather. To this line of cloud others are added, or as it were propagated from the sides in an oblique or transverse direction the whole having the appearance of net-work.

The *Cumulus*, is a dense mass of rolling clouds rising from a horizontal base. The name denotes a heap or pile; it is sometimes called the stacken-cloud, since the masses of which it is composed seem stacked or piled together. This cloud is generally formed during the day, but is desolved at the approach of evening, it has hence been termed the cloud of day. The *Stratus* or fall-cloud is a low cloud seeming to rest upon the earth, hence its name *stratus*, a covering. This cloud is generally formed during the night, and is sometimes called the cloud of night, it is generally dissipated by the rays of the sun and in this case is

considered indicative of fine weather. Among this variety of clouds are included those fogs and creeping mists that in summer evenings fill the valleys, remain during the night, and disappear in the morning. The formation of the cumulus is best viewed in fine settled weather, about sunrise or a little after. Small specks of cloud will be seen in the atmosphere, which seem to be the result of the gatherings of the stratus or evening mists, which rising in the morning form into small clouds whilst the rest of the sky becomes clearer. About sunrise two or more of these unite and form a *stacken-cloud*. In the evening it again subsides giving place to the stratus or fall cloud. In our engraving the cumulus is seen above and the stratus nearer the horizon. Some varieties of the cumulus are supposed to be closely connected with electrical phenomena. The hemispherical form is more perfect in fine than in changeable weather.

The *Cirro-stratus* is often called a mackerel sky, and is seen in fine summer evenings, it is generallly called the wave-cloud on account of its frequent alterations of figure. It is formed at a great height and presents many varieties and is sometimes seen as a thin extensive sheet covering the heavens, and it is this form of the cloud in which the halos appear, which are thought to indicate rain, and when the sun sets apparently shrouded in a dense stratum of this cloud it is a sure indication of a wet morning. A

form of the cirro-stratus called the *cymoid* cirro-stratus, consisting of rows of little clouds curved in a peculiar manner, is a sure indication of coming storms. Its most common form however is a flat horizontal cloud consisting of waving bars or streaks, confused in the middle, but more distinct at the ends or edges.

The *Cirro-cumulus* consists of extensive beds of small white clouds called in Germany little sheep. It is sometimes called the *sonder i. e.* sunder-cloud. When the component clouds towards evening are large and well defined, and distinct from each other it is considered to indicate fine weather, on the contrary, when the little clouds are round and compact, accompanied by the cumulo-stratus (see next figure), it is a sure indication of an approaching storm. It is to this cloud that Milton alludes.

> "To behold the wandering moon,
> Riding near her highest noon,
> Like one that hath been led astray
> Through the heaven's wide pathless way;
> And oft as if her head she bow'd,
> Stooping through a fleecy cloud."

The cirro-cumulus generally is a forerunner of warmth, indicating, particularly when the little clouds are small and round, in summer an increase of temperature, and in winter the breaking up of a frost. The connection of this cloud with thunder storms

has been frequently noticed by poets. In rainy and changeable weather it has a light fleecy texture, and is irregular in the form of its component parts, approaching to the cirro-stratus.

The *Cumulo-stratus*, or twain-cloud usually presents an horizontal base upon which the cloud appears heaped or piled up, it is of common occurrence previous to rain, and sometimes changes into the the nimbus or rain-cloud. In our figure, the cumulo-stratus is shown at the left and nimbus at the right. The cumulo-stratus is usually formed out of the cumulus, which grows denser and spreads out laterally until it overhangs its base, while the tops remaining distinct seem like so many snow-capped mountains, or rocks piled up. When the cumulo-stratus increases in density and blackness, indicating rain, the *nimbus* or rain-cloud is formed. As soon as the actual rain commences the blackness is changed into a dark gray or slaty color. After the rain the clouds separate and form again cumuli, cirri, and cirro-cumuli, which float in the upper regions of the atmosphere, while the broken fragments of the nimbus sail along in the currents of wind below.

It often happens that a cloud, in descending, enters a stratum of air warmer than itself and is again converted into vapor and

absorbed, a remarkable appearance of this sort is observed on the Table Mountain at the Cape of Good Hope. "Its flat top, called the Table Land, is about two miles in length from east to west, and of various breadths, but nowhere exceeding a mile. The height is estimated at 3500 feet above the sea. It is a common saying among the inhabitants of Cape Town, that when the Devil spreads his table cloth upon the mountain you may look for a strong south-east wind. In the whole system of meteorology there is not a more infallible prognostic. The Devil's tablecloth is a thin sheet of white vapor which is seen reaching over the edge of the precipice, while the sky all around is clear and unclouded. The rapidity of its descent, resembles that of water pouring over the face of a rock. The air, at the same time begins to be agitated in the valley, and in less than half an hour, the whole town is involved in dust and darkness. Instantly the streets are deserted, every window and door is shut up, and Cape Town is as still as if it were visited by the plague. Sometimes, instead of a sheet of vapor an immense cloud envelopes the mountain, and stretching out on all sides like a magnificent canopy, shades the town and adjacent country from the sun. The inferior boundary of this cloud is regulated, probably, by various circumstances, among others, by the strength of the wind, and the temperature of the air in the Table Valley. The influence of the latter is to be inferred from the fact, that though the cloud never descends more than half way into the hot parched amphitheatre of Cape Town, it may be observed on the side of Camp's Bay, rolling down in immense volumes to the very sea, over which it sometimes stretches farther than the eye can follow it. Nothing can be more singular than the appearance of this cloud. It is continually rushing down to a certain point on the side of the mountain and there vanishing. Fleeces are seen from time to time, torn from its skirts by the strength of the wind, floating and whirling, as it were in a vortex, over the town, and then gradually dissolving away. But the main body remains, as it were, nailed to the mountain, and bids defiance to the utmost efforts of the gale. There is a constant verdure maintained on this mountain from the moisture deposited from the atmosphere.

CHAPTER IV.

Climate.

"The body, moulded by the clime, endures
Equator heat, or hypoborean frost,
Except by habits foreign to its turn,
Unwise you counteract its forming pow'r."
Armstrong.

In the present chapter we shall very briefly consider the prominent causes which affect the climate of the various portions of the earth's surface. The subject is a very important one and we can do little else than give the great outlines, and must therefore refer the reader to the more elaborate works of Leslie, Daniell, and Kaemtz.

The primary cause of all heat upon the surface of the earth, and its superincumbent atmosphere, is the sun, whose rays may also be regarded as the source of all life upon our planet. In the preceding pages, we have, somewhat at length, illustrated the manner in which the sun apparently changes its position in the heavens, traversing during the year through the twelve signs of the Zodiac, in the path called the *ecliptic*, which is inclined at an angle of 23° 28′ to the celestial equator, which it crosses in two opposite points called the equinoctial points.

The celestial equator, we have shown to be in the same plane as the equator upon the earth, consequently, as the earth turns on its axis, it will happen that the rays of the sun, whenever it may be situated in the celestial equator, *i. e.* at the time of the equinoxes, will fall vertically, or perpendicularly upon all those places situated upon or near to the terrestrial equator. Twice a year, viz: on the 21st of March and the 21st of September, the sun is in those points of the ecliptic which cross the equator, and at this time its rays are vertical at noon at the equator, as we have just de-

scribed. At these seasons of the year the changes from winter to spring, and summer to autumn, commence, and the sun is said to be *crossing the line.*

The distribution of heat in the neighborhood of the equator is tolerably equal, for twice during the year, viz: March 21st and September 21st, the sun's rays fall vertically, and they do not fall very obliquely at any time between these two periods. From the 21st of March, the sun begins to move northword of the equator apparently, until at the 21st of June, its angular distance from the equator amounts to 23° 28′. This is the angle which the line S S′ makes with the line E E′, see the figure on page 57, the former representing the plane of the ecliptic, the latter the plane of the equator. At this time, as the earth turns on its axis, the sun is vertical at noon at all those places which lie in a circle drawn upon its surface parallel to the equator, and at an angular distance of 23° 28′ north of it. This circle is called the tropic of Cancer, for a reason we have already explained. From the 21st of June to the 21st of September, the sun approaches the equator, which it crosses on the latter named day, it then moves farther south, until, on the 21st of December, its angular distance from the equator becomes 23° 28′, and, if we suppose a circle drawn upon the earth at a distance of 23° 28′ from the equator, but south of it, the sun will now be vertical at all places situated on or near to this circle, which, for reasons already given, is called the tropic of Capricorn. All places therefore lying upon these tropics, receive once in the year, the sun's rays perpendicularly at mid-day, this being on the 21st of June for the tropic of Cancer and the 21st of September for the tropic of Capricorn. At all places within these two tropics the sun is vertical at noon twice in the year; and at all places without or beyond them, it is never vertical. The nearer we approach the tropics, leaving the equator, the more marked are the different seasons of the year, and for the following reason; once during the year, as we have just remarked, the sun's rays fall vertically at the tropics, and once they make an angle of 47° or twice 23° 28′, with the direction of the plumb-line, and which is the angle S S′ C′, see figure on page 57, falling consequently, with considerable obliquity. The hot-

test and coldest seasons being separated by a period of half a year, differ very considerably from each other in their temperature. The whole terrestrial zone lying between these two tropics is called the *hot zone*, or torrid zone. When the sun's distance from the equator north is the greatest possible, *i. e.*, when it is in the tropic of Cancer or at the point VI, see figure, page 80, the north pole of the earth is illuminated, and the south pole in darkness, as represented in the figure, page 109. If we suppose a circle traced upon the earth as shown at *c d*, it is evident that as the sun now illuminates all within this circle, the day will be to a spectator situated upon it, 24 hours in length, or in other words visible during a complete revolution of the earth on its axis. A similar circle shown at *g h*, indicates the position in the southern hemisphere where the longest day is 24 hours. These two circles are called, the former the Arctic, and the latter the Antarctic, the former is situated 23° 28′ from the north pole, and consequently 66° 32′ north of the equator, and the latter at the same distance from the south pole, and south of the equator. The terrestrial zones included between the tropics and the polar circles, are called the northern and southern temperate zones. The four seasons of the year are most strongly characterized in these zones, and the general rule for the dimunition of heat is, directly as the distance from the equator. Within the polar circles are the northern and southern frigid zones. As the earth turns upon its axis from west to east, the sun is apparently caused to rise in the east, move over the heavens, and set in the west, thus producing the alternation between day and night. During the day, the surface of the earth is warmed by the rays of the sun, but when these are withdrawn at night, the heat is radiated to the heavens and lost, during the night therefore the surface of the earth is cooled. We shall presently see that the vicissitudes in climate varying with the latitude, are mainly due to the unequal lengths of day and night. Under the equator the days and nights are very nearly equal, throughout the year, each lasting 12 hours. As soon, however, as we leave the equator, the length of the day varies according to the season of the year, and the difference between the day and night becomes more striking as we approach

nearer the poles. The following table exhibits the length of the longest day for different geographical latitudes.

Polar elevation.	Length of the longest day.
0	12 hours,
16° 44′	13 "
30° 48′	14 "
49° 22′	16 "
63° 23′	20 "
66° 32′	24 "
67° 23′	1 month,
73° 39′	3 months,
90°	6 months.

Upon examining this table it will be perceived that within the tropics, the length of the longest day never varies much from that of the night, and hence, as before observed, the temperature is tolerably equal. In higher latitudes the rays of the sun strike more obliquely than within the tropics, yet the day so much exceeding the night, more heat is gained during the day than is radiated during the night, and thus, what is lost in intensity, is gained in the length or duration, and it thus happens that during the summer it may be very hot, even at places far removed from the equator. At St. Petersburgh, for instance, during a hot summer the thermometer frequently rises to 86°. On the other hand, in winter, at the same latitudes, the days become as much shorter than the nights, as the nights were previously shorter than the days; hence, since the sun's rays fall very obliquely, and are therefore very feeble in their action, the earth radiating much more heat at night than it receives during the day, the winter temperature is very low, the difference between winter and summer temperature will therefore, generally be greater, the farther we remove from the equator.

"At Bogota, which is 40° 35′ N. of the equator the difference of temperature between the hottest and coldest month amounts to only 3°; in Mexico (19° 25′ N. lat.) this difference is 14°; at Paris, (48° 50′ N. lat.) 48°, and for St. Petersburgh, (59° 56′ N. lat.) 57°."

It appears from what has been said, that within a distance of 10 or 15 degrees of the equator or equinoctial line, the difference between summer and winter temperature is trifling, but when we

get as far north as the tropics, this differencee becomes very sensible, and it has been truly observed, that the torrid zone may be divided in three, viz: the equatorial belt, extending 10 or 15 degrees from the equator, and the two belts north, and south, between this and the tropics. The equatorial belt, properly so called, is temperate compared with the two others, the zone of the tropic of Cancer being the hottest and least habitable part of the globe. The greatest natural heat of which we are aware, has been observed at Bagdad, at 33 degrees of N. lat., being 111° Fahrenheit. There are many reasons why the equatorial belt should have a uniform and somewhat mild temperature; the clouds, the great rains, the nights naturally cool and equal in length to the days, and the great evaporations. As we go farther from the equator the difference between the summer and winter temperature becomes more marked, the summers being, on account of the protracted heat of the day, very warm even in high latitudes, and the winters extremely cold. Thus, even as far from the equator as the 65th parallel of latitude, the power of the solar beams accumulating through the long days, produces an effect which might be expected only in the torrid zone. There have been examples of forests having been set on fire, and of the pitch melting on the sides of ships. Notwithstanding the general law of the decrease of mean temperature as we recede from the equator, yet it is impossible to draw any conclusion as to the climatic relations of a place from its geographical latitude. If the earth's surface was entirely homogeneous, either covered by water, or by land, possessing the same capacity for heat, then the geographical latitude of a place would determine its climate, and all places having the same latitude would have a similar climate. This however, is not the case, for although the local temperature of a country depends very much upon its latitude, yet the nature of its surface, the proportion of humidity, the distance from the sea, or from lakes or mountains, and its elevation above the ocean, and the nature of the prevailing winds, all have a share in determining the climate. The decrease of heat as we recede from the equator follows different laws in the two hemispheres, being greater in the southern than in the northern, and is also affected by the longi-

tude. The true distribution of heat over the earth's surface can therefore only be determined by a long series of observations. Baron Humbolt with unwearied zeal, has collected the data for, and laid the foundation of, a scientific meteorology. The instrument employed to measure the intensity of heat, called a thermometer is to well known to need any description here. The thermometer in ordinary use is what is called Fahrenheit's, the scale being graduated to show 212° for the heat of boiling water, and 32° for the temperature of melting ice, or freezing water. The zero or commencement of the scale, is the temperature of a mixture of salt and ice, or snow, and which was once supposed to be the greatest artificial cold. The thermometer called Reaumer's is used in some parts of the continent of Europe, the freezing point of water being zero, or the commencement of the scale, and the space between this and the boiling point of water is divided into 80°. The thermometer now used in France, and the greater part of the continent of Europe, is called Centrigrade; the scale of this thermometer is graduated into 100 degrees from the freezing, to the boiling point of water; this division of the scale appears the most natural, and has been adopted by law in the state of New York.

In employing the thermometer to observe the general temperature of the air at any particular season of the year, it will generally be sufficient to make two observations in the morning, viz: at 4h, and 10h, and two in the afternoon at the same hours, the mean of the observations will give the mean temperature for the day very exactly; thus, suppose the observations made at these hours to be 50°, 80°, 90°, and 60°, adding these all together, and dividing their sum 280°, by 4 gives 70° for the mean temperature of the day. When we know the mean temperature of all the days of a month, we can in like manner determine the mean temperature of that month. We can likewise determine in a similar manner the mean temperature of the year, or of summer, and winter. The mean annual temperature, of a place not subject to very great local changes, such as the clearing up of forests, or drying up of streams and rivers, is very nearly constant. Thus, the extreme difference of mean annual tempera-

ture of Paris for a series of 16 years was only 4°. We can thus by a series of well directed observations, determine the general climatic relations of various continents, and the result of such observations are in some instances very different from what would be inferred from mere theoretical considerations. It is found that the decrease of heat as we recede from the equator, follows different laws in the two hemispheres. The subjoined table shows the mean annual temperatures of Western Europe and North America, continued from the equator.

Latitude.	Old World.	New World.	Difference.
0°	81.5°	81.5°	0°
20	77.9	77.9	0
30	70.7	67.1	3.6
40	63.5	54.5	9.0
50	50.9	38.3	12.6
60	41.0	25.0	16.0
70	33.0	0.0	33.0

From this table it appears that the decrease of temperature, or increase of cold is much more rapid in America than in Europe. Baron Humbolt, who has added more to our knowledge of the distribution of temperature over the globe, than any other who has labored in the same boundless field, has proposed a system of *isothermal* lines connecting different places having the same mean annual heat. The differences between the mean annual temperature of places upon the same parallels of latitude are thus presented to the eye in a very striking manner. On the next page will be found a little chart of isothermal lines for every 5° in Mercator's proportions. It will be seen that the mean annual heat of Eastern Asia and Eastern America, are much nearer than of Eastern America and Western Europe. A simple inspection of this map will give a clearer idea of the variation of isothermal lines from the parallels of latitude. Thus, for instance, the mean annual heat at the North Cape, is 32°; whilst Nain on the coast of Labrador, 14° south of the North Cape, has a mean annual heat of 25°. The table which we give contains a general summary of Baron Humbolt's observations deduced from a very great number of observations. The locality of a place very

32
41
50
59
68
77

much affects the climate, and as a general rule the western sides of continents and large islands, are warmer than the eastern. Certain portions of the globe, which from their nearness to the equator would be extremely warm, are rendered tolerably cool by their elevated situations. This is the case with much of the tropical land in America, which is so raised that it rivals even European climates in mildness and agreeable temperature. The air of these elevated tropical districts is remarkably pure and transparent, and the winds which sweep over the plains, are cooled by their passage down the snow-capped mountains, which rear their bright summits to the skies. The vast expanse of table-land, forming the empire of Mexico is of this character, being elevated 7000 feet above the level of the ocean. This land in many parts has the fertility of a cultivated garden. The plains of Columbia in South America, and indeed all along the ridge of the Andes, are similarly situated. The chart which we have given represents the direction of the isothermal lines, or lines connecting places which have the same mean annual heat. It will be evident that places may thus be situated on the same isothermal line, which have very unequal mean temperatures of summer and winter. We need only refer to the table on page 157, to be convinced of this. Thus, the mean annual temperature of London, and Cambridge, Mass. is the same, 50°36′; but the mean temperature o the warmest month at London is 64°40′, while at Cambridge it is 72°86′, and of the coldest month, at London 37°76, at Cambridge 29.84, London therefore has a colder summer and a warmer winter than Cambridge. The reason of this, is undoubtedly, the insular situation of the former, for as a general rule the extremes of temperature are experienced in large inland tracts, and little felt in islands remote from continents. The difference between the mean temperature of summer and winter is nothing at the equator, and increases continually with the latitude. When the mean annual temperature is low the difierences between the extremes of the seasons is great, and the contrary.

The effect of climate upon the geographical distribution of plants and animals is very marked. Each, generally has its pe-

culiar climate where it thrives best, and beyond certain limits it ceases to exist. The successive zones of vegetation, as we recede from the equatorial regions, have sometimes been supposed to be represented by the different altitudes upon the mountains under the equator, as it is evident we have in ascending from the valleys to their snow-capped summits, every variety of temperature. The analogy fails however in one essential point, for as we ascend the mountains the pressure of the atmosphere is continually diminished and it is evident that less nutriment is thus afforded for the growth of the plant. The influence which the variations of climate alluded to, must have upon vegetation is very evident, thus in many parts of Siberia, wheat and rye are raised upon a soil which is constantly frozen at a depth of three feet, while in Iceland, where the mean temperature of the year is much warmer, and the winter's cold but inconsiderable, it is not possible to raise any of the *ceralia* or common grains, as the low summer temperature does not suffer them to ripen. It is for the same reason that the vine does not flourish in England, for although it can endure a tolerably great degree of cold, yet it requires a hot summer to make the fruit ripen, and yield a drinkable wine. There is no subject connected with meteorology which requires a more careful, and studied investigation than that of climates. So many causes influence the temperature of the air, and some of them are so variable, that no labor short of a well conducted series of observations, extending through a long course of years can give a satisfactory result. In the brief account we have given, we have been able to present little else than the leading facts, and must refer the reader to the writings of Leslie, De Candolle, Mirbel, and Humbolt, for further information.

TABLE

Exhibiting the mean temperature of various places compiled principally from the observations of Baron Alex. Von Humboldt.

Isothermal Bands.	Names of Places.	Position: Lat.	Long.	Hght.	Mean temperature of the Year.
		° ′	° ′	Feet	°
Band from 32° to 41°.	Melville Island	74 47	110 48w.	0	— 2.00
	Nain	57 8	61 20w.	0	+ 26.42
	Enontekies	68 30	20 47E.	1356	26.96
	Hospice de St. Gothard	46 30	8 23E.	6390	30.38
	North Cape	71 0	25 50E.	0	32.00
	Ulea	65 3	25 26E.	0	35.06
	Umea	63 50	20 16E.	0	33.26
	St. Petersburg	59 56	30 19E.	0	38.84
	Drontheim	63 24	10 22E.	0	39.92
	Moscow	55 45	37 32E.	970	40.10
	Abo	60 27	22 18E.	0	40.28
Band from 41° to 50°.	Upsal	59 51	17 38E.	0	42.08
	Stockholm	59 20	18 3E.	0	42.26
	Quebec	46 47	71 0w.	0	41.74
	Christiania	59 55	10 48E.	0	42 80
	Convent of Peissenberg	47 47	10 34E.	3066	42.98
	Copenhagen	55 41	12 35E.	0	45.68
	Kendal	54 17	2 46w.	0	46.22
	Falkland Islands	51 25	59 59w.	0	46.94
	Prague	50 5	14 24E.	0	49.46
	Gottingen	51 32	9 53E.	456	46.94
	Zurich	47 22	8 32E.	1350	47.84
	Edinburgh	55 57	3 10w.	150	47.84
	Warsaw	52 14	21 2E.	0	48.56
	Coire	46 50	9 30E.	1876	48.92
	Dublin	53 21	6 19w.	0	49.10
	Berne	46 5	7 26E.	1650	49.28
	Geneva	46 12	6 8E.	1080	49.28
	Manheim	49 29	8 28E.	432	50.18
	Vienna	48 12	16 22E.	420	50.54

Isothermal Bands.	Names of Places.	Position.					Mean temperature of the Year.
		Lat.		Long.		Hght.	
		°	′	°	′		°
Band from 50° to 59°.	Clermont	45	46	3	5E.	Feet 1260	50.00
	Buda	47	29	19	1E.	494	51.08
	Cambridge, Mass.	42	22	71	7W.	0	50.36
	Paris	48	50	2	20E.	222	51.08
	London	51	30	0	5W.	0	50.36
	Dunkirk	51	2	2	22E.	0	50.54
	Amsterdam	52	22	4	50E.	0	51.62
	Brussels	50	50	4	22E.	0	51.80
	Franeker	52	36	6	22E.	0	51.80
	Philadelphia	39	56	75	10W.	0	53.42
	New York	40	40	73	58W.	0	53.78
	Cincinnati	39	6	84	27W.	510	53.78
	St. Malo	48	39	2	1W.	0	54.14
	Nantes	47	13	1	32W.	0	54.68
	Peking	39	54	116	27E.	0	54.86
	Milan	45	28	9	11E.	390	55.76
	Bordeaux	44	50	0	34W.	0	56.48
Band from 59° 68°.	Marseilles	43	17	5	22E.	0	59.00
	Montpellier	43	36	3	52E.	0	59.36
	Rome	41	53	12	27E.	0	60.44
	Toulon	43	7	5	50E.	0	62.06
	Nangasaki	32	45	129	55E.	0	60.80
	Natchez	31	34	91	24W.	180	64.76
68° to 72°.	Funchal	32	37	16	56W.	0	68.54
	Algiers	36	48	3	1E.	0	69.98
Band above 72°.	Cairo	30	2	30	18E.	0	72.32
	Vera Cruz	19	11	96	1W.	0	77.72
	Havana	23	10	82	13W.	0	78.08
	Cumana	10	27	65	15W.	0	81.86

CHAPTER V.

Optical Phenomena.

"Why do those cliffs of shadowy tint, appear
More sweet than all the landscape smiling near?
'Tis distance lends enchantment to the view,
And robes the mountain in its azure hue."

Campbell.

In the present chapter we shall describe and explain the general optical appearance of the sky, and some of the more striking optical phenomena connected with our present subject. When the rays of the sun strike the minute particles of air, which, according to circumstances, may be more or less dense, or charged with watery vapor, they are either reflected, or transmitted; in either case sometimes returning the most beautiful colors. It is a fact to well known to need much illustration from us, that light, whenever it is refracted by any medium, such as glass or water, is always separated into the prismatic colors, whenever the surfaces of the medium are curved, or inclined to each other. It is not however, so generally understood, that these different colored rays have different powers of penetrating through various media, and that they move with different velocities. This however, is susceptible of demonstration, and it is to this that the beautiful colors of an autumnal sunset are owing. The red, violet and orange rays have the greatest velocity, and penetrate the thick dense strata of horizontal air, with the greatest facility, giving us the rich and brilliant hues of sunset and sunrise, tinging the morning and evening clouds with glowing red, and gold; and the sober twilight, with that purple fading into gray which is assumed when the ruddy glare of sunset is tempered by the azure of the sky. Since the red and yellow rays which compose white light, are transmitted by the air, unattended by the blue rays, it follows that these latter must be reflected, hence the beautiful

blue of the sky, and the bright azure which tinges the distant mountains when viewed through a considerable body of intervening air, and especially, when charged with watery vapor Perhaps this one feature, which so mellows down the distant outlines of the hills and buildings, is the most pleasing feature of the landscape. It is from strict attention to the phenomena dependent upon this principle, that the artist derives his pleasing skill in picturing objects of varying distance, introducing skillfully the color of the intervening air. How simple, and yet how beautiful are the various contrivances which administer, not to the wants merely, but to the pleasures of man. It is the same simple cause which tints the bright blue sky, and its beautiful clouds, here piled in snowy masses, and there sundered into a thousand fleecy shapes; which lights the west with a golden glow, and fringes the extended clouds that skirt the horizon with the brightest hues of red and gold; and it is owing to the peculiar nature of the red rays of the spectrum, that the sun appears a dull red globe when viewed through air highly saturated with watery vapor, or through clouds and fogs.

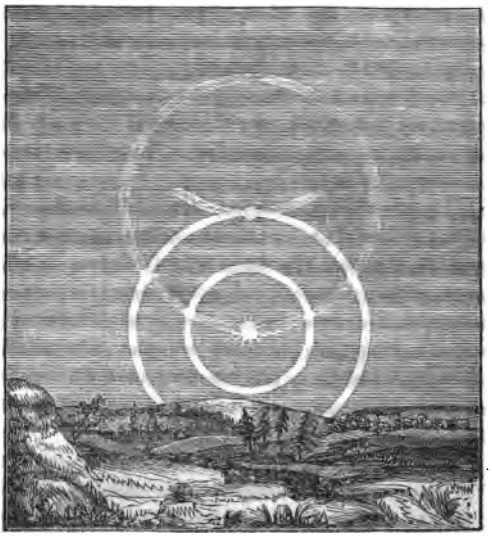
When the rays of the sun strike upon a cloud, they are copiously reflected, but partly absorbed by the minute suspended globules, and the quantity of light which penetrates through the nebulous medium is always much less than what traverses an equal body of air, and this gives the clouds their varying shades of color. That the color of the sky is owing to reflected light, is sufficiently evident from the fact, that it becomes darker and darker, as we ascend into the higher regions of the atmosphere, through which, the blue rays find a ready passage. Were it not for the reflecting power of the atmosphere, and the clouds, we would have no softening of the day into night, as now, by the twilight; but instantly, at sunset, darkness would veil the earth, and every cloud that obscured the sun would cause a total eclipse. The tint of the sky is deeper in the torrid zone than in high latitudes, and in the same parallel it is fainter at sea than on land, this may be attributed to the aqueous vapor continually rising towards the higher regions of the air from the surface of the sea. The presence of much moisture is also easily detected by the

paleness of the sun at sunset, by means of which, sailors are accustomed to presage a storm.

The colored rings or halos which are often seen surrounding the sun and moon are evidently occasioned by very thin vapor diffused through the atmosphere. They are supposed chiefly to encircle the moon, but scarcely a day passes without light misty clouds, when at least portions of halos may be seen near the sun, and in order to perceive them, it is only necessary to remove the glare of light which makes the delicate colors appear white. Thus, if we examine the reflection from a smooth surface of water, we will perceive that the sun gilds the fleecy clouds with segments of beautifully colored rings. This effect is more distinctly seen, if the rays from a hazy or a mottled sky, be received upon a sheet of white paper held before a small hole in the window shutter in a dark room. But even when the sun shines from an azure firmament, circles of the richest tints may be produced by experiment, thus, holding a hot poker below, and a little before the small hole in the shutter, above mentioned, throw a few drops of water upon it, and the sun will be painted upon the paper like the glowing radiations of the passion flower.

Halos are produced by what is termed the diffraction of light, *i. e.* the rays of light in passing near the edges of a body appear to be bent from their rectilineal course. This diffraction may be easily observed by viewing objects through a minute hole, it will be found that the edges of straight bodies will be curved if viewed near the edge of the hole, and a line of bright white light, will appear tinged with orange on the side nearest the edge of the hole, and with blue upon the other. Halos are much more common in the northern latitudes than in warmer climates, a fact which is owing doubtless, to frozen particles of water floating in the air, though Humboldt remarks that lunar halos are much rarer in the northern than the southern countries of Europe, and seen more especially when the sky is clear and weather settled. He observes that in the torrid zone they appear almost every night, and often in the space of a few minutes disappear several times. Between the latitude of 15° N. and the equator, he has seen small halos around the planet Venus. The next figure exhibits

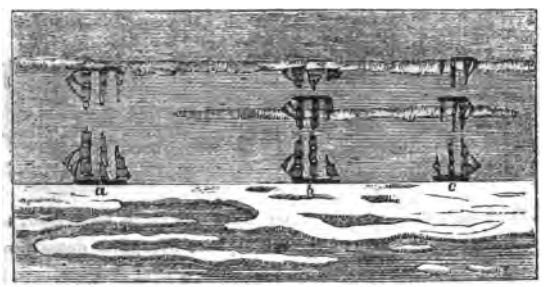
a halo seen around the sun by Scheiner in 1630. In this fine set of halos mock images of the sun at the intersection of the circles, termed parhelia and anthelia may be observed. These are



quite common in the arctic regions, presenting the gorgeous appearance of intersecting luminous arches, studded with opposite and transverse images of the sun; the formation of these, is undoubtedly owing to the combined reflections of the rays from the natural faces of the snowy crystals floating abundantly in the air. Fringes of colored light, similar to those which form halos, may be observed in looking through the fibres of a feather, or thin streaks of grease rubbed over a glass plate. If a small hole is made in a piece of tinfoil, and held close to the eye, a halo will be seen upon looking at the sun through it, very near to his disc. By comparing the artificial halos thus formed with the natural ones, Prof. Leslie endeavored to ascertain the size of the globules producing the halos, it being inferred that an aqueous

globule of the same dimensions as the perforation might produce a similar halo. He found them to vary from the 5000th to the 50,000th part of an inch in diameter. When the halo approaches nearest to the body, the largest globules are floating, and therefore the atmosphere is surcharged with humidity. Hence the justness of the vulgar remark, that a dense halo close to the moon portends rain.

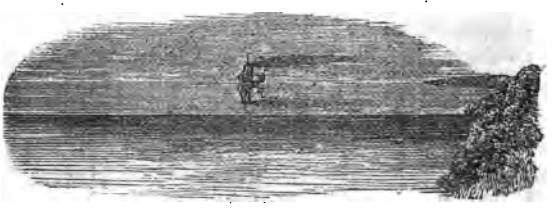
The elevation of coasts, ships, and mountains, above their usual level has long been known under the name of *looming*, and the name *mirage* has been given by the French to the same phenomena. The curious spectacle often witnessed at the straits of Messina called the Fata-Morgana, belongs to the same class of optical phenomena. One of the most interesting cases on record was witnessed by Capt. Scoresby, in the Arctic sea. While navigating the Greenland sea on the 28th of June, 1820, he observed about eighteen or nineteen sail of ships at the distance of from ten to fifteen miles. He saw them from the mast-head beginning to change their form, one was drawn out or elongated in a vertical plane, another was contracted in the same direction, one



had an inverted image immediately above it as at *a;* and two at *b* and *c*, had two distinct inverted images in the air; along with these images there appeared images of the ice, as at *b* and *c*, in two strata, the highest of which had an altitude of about fifteen degrees. In a later voyage performed in 1822, he saw his father's ship when below the horizon. "It was" says he, "so well defined that I could distinguish by a telescope every sail, the genera

rig of the ship, and its particular character, insomuch that I confidently pronounced it to be my father's ship, the Fame, which it afterwards proved to be, though in comparing notes with my father, I found that our relative positions at the time gave our distance from one another very nearly thirty miles, being about seventeen miles beyond the horizon, and some leagues beyond the limit of direct vision. I was so struck by the peculiarity of the circumstance, that I mentioned it to the officer of the watch, stating my full conviction that the Fame was then cruising in the neighboring inlet."

A fine exhibition of mirage was witnessed at Cleveland on the afternoon of April 12, 1848, at half past three o'clock, P. M., and which is represented in the engraving below. The steamboat New Orleans left Fairport, 30 miles from Cleveland, at 2h. 10m. P. M., and consequently at the time the mirage was seen, was below the horizon; with a glass however, two distinct images were perceived elevated in the air, and a point of land ordinarily invisible could be easily observed. This phenomenon was witnessed by a large number of persons.



These phenomena, which we have repeatedly witnessed, are owing to peculiar states of the atmosphere as regards density and moisture. Every one is aware that a straight stick appears to be crooked when thrust into the water, bending at the plane of the surface, and when a ray of light passes from one medium to another this *refraction* or bending always occurs, in a greater or less degree, according to the difference of density in the media, or the peculiar refracting power. The effect of atmospheric refraction is always to make a body appear higher than it really is, thus we see the sun, actually after sunset, the rays which proceed from

it up into the sky, being so bent downwards as to reach the eye. Among the most beautiful phenomena that greet the eye when contemplating the heavens in a serene night, but more particularly in autumn, the shooting stars, or meteors are preëminent; at almost all seasons of the year an attentive observer will perceive them moving swiftly over the heavens, and occasionally leaving a long luminous train behind. Their origin has not been satisfactorily traced, yet, since their occurrence in unusual numbers, and splendor, is now proved to be periodical, it is supposed they may be in some way connected with that beautiful luminous appearance called the zodiacal light. This is the opinion of Prof. Olmsted, who has devoted much time to this subject, and has been a careful investigator of the facts connected with meteors and the zodiacal light for many years. The "falling stars" seem to have been observed in the earliest times, and were considered as a presage of violent winds, thus Virgil —

> "And oft before tempestuous winds arise,
> The *seeming* stars fell headlong from the skies,
> And shooting through the darkness, gild the night
> With sweeping lines, and long trains of light."

The number of meteors visible at ordinary seasons of the year in one night, is quite limited, but we must remember that many of them are very small, and probably too distant to be observed by the unassisted eye. We have often witnessed the passage of meteors through the field of view of a night-glass when sweeping the heavens for comets, and have occasionally seen some very beautiful trains not at all visible to the unassisted eye.

In the year 1833 a most remarkable display of falling stars was witnessed in the United States, but was not seen either in South America or Europe. It occurred on the morning of Nov. 13th, and exceeded in magnificence any natural phenomenon we have ever witnessed; the whole heavens seemed glowing with fire-balls, which were falling in all directions. For many successive years this exhibition was repeated on the same morning, occurring most abundantly at about 4 o'clock, and apparently radiating from one centre, but each year their numbers diminished, and we believe that now, no more are visible upon on that night

than upon any other. Two other periods of unusual brilliancy seem to have been pretty well determined, viz: April 21st, and Aug. 10th. It is our opinion that these meteors, and the zodiacal light, are both of terrestrial origin, *i. e.* have their origin within the limits of our atmosphere. The greatest height at which these bodies occur is supposed to be about 2300 miles: at this height the atmosphere would be excessively rare, but it is probable that the upper strata are composed of more inflammable materials than common air; hydrogen gas is continually being emitted by the great laboratory of nature, and ascends to the upper regions, here, when released from pressure it may expand to at least the distance, (and beyond it), where meteors occur. Sir John Leslie thus accounts for the lambent glow of the heavens in a clear night, supposing this stratum of highly inflammable gas to be phosporescent. We might perhaps trace the zodiacal light to the same source. This remarkable appearance is most conspicuous

in the finer climates and near the vernal equinox, and has often been ascribed to the extension of a supposed luminous atmos-

phere about the sun. Laplace seems to have shown satisfactorily that such an atmosphere, far from extending to the earth, would not reach to even the orbit of Mercury. If this be so, we must either adopt the theory of Von Humboldt, who supposes it to be a luminous ring surrounding the sun, or conclude it is of terrestrial origin. The preceding cut represents this beautiful phenomenon. It may be seen in our northern latitudes in the spring months after sunset, reaching up in the plane of the ecliptic towards the Pleiades long after sunset; it gradually sets with the stars and may again be seen in the morning before sunrise. According to Sir John Leslie, the sun, shining upon the higher strata of the atmosphere, which he supposes phosphorescent, would form a large luminous circle which we would see surrounding the sun at most, provided it was not eclipsed by his superior brilliancy; after sunset it would appear as a segment of a circle, did not the vapors of the horizon obscure its extreme and faintest limits, hence it appears lenticular, or lens shaped as represented in the engraving.

We shall conclude this chapter with a description of that well known, but yet unexplained phenomenon the Aurora Borealis or northern lights. In the high northern latitudes, beautiful displays of the aurora are witnessed, and they serve to enliven the long winter nights with their bright coruscations. In our latitude the exhibitions are of a less beautiful character, and rarer, but yet so frequent that they are familiar to all. It generally appears like a bank, or cloud of light, of a pale yellow color, resting upon the northern horizon, occasionally emitting streamers which shoot up towards the zenith, and then fade, revive again, and subdivide. At other times it is seen as a luminous arch rising a short distance above the horizon, its highest altitude being in the magnetic meridian; from this, streamers ascend, and if the display is a fine one, will appear to unite in a circle nearly in the zenith, called the corona. It is a remarkable fact that great displays of the aurora are always proceeded by a disturbance of the magnetic needle. Like the meteoric showers, there seems to be a periodical return of the auroral displays in unusual splendor, after definite intervals. One of these returns, which we well remember, occurred at intervals from November 1835, to May 1836. The

two following descriptions are from the pen of Professor Olmsted. The first display took place on the 17th of November 1835, the last on the 23d of April 1836.

"On the 17th of November, 1835, our northern hemisphere was adorned with a display of auroral lights remarkably grand and diversified. It was observed at fifteen minutes before seven o'clock, when an illumination of the whole northern sky, resembling the break of day, was discernable through the openings in the clouds. About eighteen degrees east of north, was a broad column of shining vapor tinged with crimson, which appeared and disappeared at intervals. A westerly wind moved off the clouds, rendering the sky nearly clear by eight o'clock, when two broad, white columns, which had for some time been gathering between the stars Aquila and Lyra on the west, and the Pleiades and Aries on the east, united above, so as to complete a luminous arch, spanning the heavens a little south of the prime vertical. The whole northern hemisphere, being more or less illuminated, and separated from the southern by this zone, was thrown into striking contrast with the latter, which appeared of a dark slate color, as though the stars were shining through a stratum of black clouds. The zone moved slowly to the south until about nine o'clock, when it had reached the bright star in the Eagle in the west, and extended a little south of the constellation Aries in the east. From this time it began to recede northward, at nearly a uniform rate, until twenty minutes before eleven, when a vast number of columns, white and crimson, began to shoot up, simultaneously, from all parts of the northern hemisphere, directing their course towards a point a few degrees south and east of the zenith, around which they arranged themselves as around a common focus. The position of this point was between the Pleiades and Alpha Arietis, and south of the Bee.

Soon after eleven o'clock, commenced a striking display of those undulatory flashes denominated merry dancers. They consisted of thin waves or sheets of light, coursing each other with immense speed. These undulations which play upon the surface of a field of rye, when gently agitated by the wind, may give the reader a faint idea of these auroral waves. One of these

crimson columns, the most beautiful of all, as it ascended towards the common focus crossed the planet Jupiter, then at an altitude of thirty-six degrees. The appearance was peculiarly interesting, as the planet shone through the crimson clouds with its splendor apparently augmented rather than diminished.

A few shooting stars were seen at intervals, some of which above the ordinary magnitude and brightness. One that came from between the feet of the Great Bear, at eight minutes after one o'clock, and fell apparently near to the earth, exhibited a very white and dazzling light and as it exploded scattered shining fragments very much after the manner of a sky rocket.

As early as seven o'clock, the magnetic needle began to show unusual agitation, and after that it was carfully observed. Near eleven o'clock, when the streamers were rising and the corona forming, the disturbance of the needle was very remarkable, causing a motion of one degree and five minutes, in five minutes of time. This disturbance continued until ten o'clock the next morning, the needle having traversed an entire range of one degree and forty minutes, while its ordinary deflection is not more than four minutes.

Another writer, speaking of the same appearance, says—We can compare the spectacle to nothing but an immense *umbrella* suspended from the heavens, the edges of which embraced more than half the visible horizon; in the south-east its lower edge covered the belt of Orion, and farther to the left the planet Jupiter shone in all its magnificence and glory, as through a transparency of gold and scarlet. The whole scene was indescribably beautiful and solemn. It was a spectacle of which painting and poetry united can give no adequate idea, and which philosophy will fail to account for to the satisfaction of the student of nature, or the disciple of revelation. The cause can be known only to HIM at whose bidding

> Darkness fled—Light shone,
> And the etherial quintessence of heaven
> Flew upward, spirited with various forms
> That rolled orbicular, and turned to stars.

The appearance of April 23d 1836, is thus described by Olm-

sted :—Last night we were regaled with another exhibition of the auroral lights, in some respects even more remarkable than that of the 17th of November. It announced itself as early as a quarter before eight o'clock, by a peculiar kind of vapor overspreading the northern sky, resembling a thin fog, of the color of dull yellow, slightly tinged with red. From a bank of the auroral vapor that rose a few degrees above the northern horizon, a great number of those luminous columns called streamers ascended towards a common focus, situated, as usual, a little south and east of the zenith, nearly or perhaps exactly at the magnetic pole of the dipping-needle. Faint undulations played on the surface of the streamers, affording sure prognostics of an unusual display of this mysterious phenomenon. The light of the moon, now near its first quarter, impaired the distinctness of the auroral lights, but the firmament throughout exhibited one of its finest aspects. The planet Venus was shining with great brilliancy in the west, followed at small intervals by Jupiter and the moon; while the larger constellations, Orion and Leo, with two stars of the first magnitude, Sirius and Procyon, added their attractions. The sky was cloudless, and the air perfectly still.

There are but few examples on record of the auroral lights displaying themselves with peculiar magnificence in moonlight.

Notwithstanding the presence of the moon, by half past ten o'clock, the auroral arches, streamers, and waves began to exhibit the most interesting appearances. No well-defined arch was formed, but broad zones of silvery whiteness, composing greater or less portions of arches, were seen in various parts of the heavens. Two that lay in the south, crossing the meridian at different altitudes, were especially observable. From each proceeded streamers, all directed towards the common focus. At the same time, those peculiar undulations called merry dancers, were flowing in broad and silvery sheets towards that point, writhing around it in serpentine curves, and often assuming the most fantastic forms. The swiftness of their motions, which were generally upward, and often with their broadest side foremost, was truly astonishing. Toward the horizon the undulations were comparatively feeble; but from the elevation of about thirty degrees to

the zenith, their movement was performed in a time not exceeding one second,—a velocity greater than we have ever noticed before, which was still distinctly progressive.

Five minutes after eleven o'clock, a few large streamers, of the whiteness of burnished silver, radiated from the common focus towards the east and the west. These were soon superseded by a mass of crimson vapor, rising simultaneously a little south of west, and north of east, and ascending towards the focus in columns eight or ten degrees broad below, but tapering above; these disappeared in about ten minutes, and the lights were subsequently a pure white, except an occasional tinge of red. During the appearance of the crimson columns a rosy hue was reflected from white houses and other favorable surfaces, imparting to them an aspect peculiarly attractive.

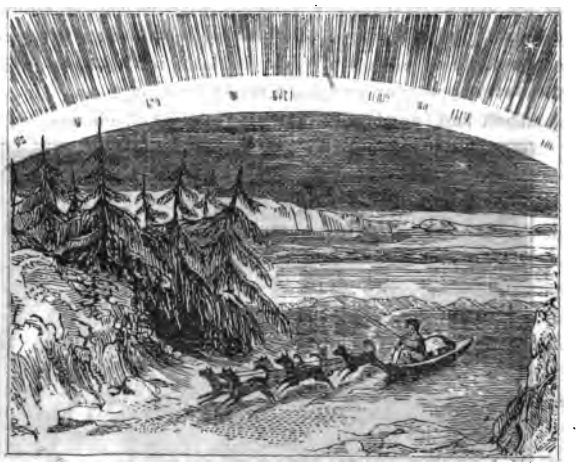
From this time until half past two o'clock, our attention was almost wholly absorbed in contemplating the sublime movements of the auroral waves: they evidently were formations entirely distinct from the columns, which either remained stationary, or shot out a broad stream of white light towards the focus, while the waves apparently occupied a region far below them.

At half past two o'clock, a covering of light clouds was spread

over a large portion of the sky, and our observations were dis-

continued. At this time, although the moon was down, yet its absence produced little change in the general illumination; the landscape appeared still as if enlightened by the moon, and it was easy to discern the time of night by a watch, from the light of the aurora."

On the preceding page, is a view of the Aurora as witnessed by the French philosophers in the year 1838—9, at Borekop, bay of Alten, coast of W. Finmark, lat. 70° N. It presented the form of a scroll with folds overlapping, and waving like a flag agitated by the wind. Its brightness varied very suddenly, and the colors changed from bright red at the base, to green in the middle portions, and yellow at the top. The brightness would diminish, and colors fade, sometimes suddenly, and sometimes by slow degrees. After this, the fragments would be gathered, and the folds reproduced; the beams seemed to converge at the zenith which was doubtless, the effect of perspective.



But it is in the Arctic regions that this phenomenon is witnessed in its greatest splendor, and presenting a variety of the most beautiful tints. In that cold region, clouds seldom obscure the sky, nothing in the form of fog or mist veils the deep blue of the

heavens, every star blazes forth like a diamond, and a thousand icy pinnacles throw back their light, accompanied with magnificent prismatic displays. The bold hunters who penetrate the arctic circle in the pursuit of the silver fox and the sable, witness its grandest exhibitions. The whole sky is lighted up with the bright coruscations, and it is said that a rushing sound, like that of winds sweeping over a distant forest is heard. The inhabitants of the Shetland islands call the streamers merry dancers.

The appearance of the aurora, and the emotions it excites, are thus beautifully described by Whittier:

A light is troubling Heaven! A strange, dull glow
Hangs like a half-quench'd veil of fire between
The blue sky and the earth; and the shorn stars
Gleam faint and sickly through it. Day hath left
No token of its parting, and the blush
With which it welcom'd the embrace of Night,
Has faded from the blue cheek of the West;
Yet from the solemn darkness of the North,
"Stretch'd o'er the empty place" by God's own hand,
Trembles and waves that curtain of pale fire,
Tinging with baleful and unnatural hues
The winter snows beneath. It is as if
Nature's last curse—the fearful plague of fire,
Were working in the elements, and the skies
Even as a scroll consuming.

Lo, a change!
The fiery wonder sinks, and all along
The dim horizon of the clouded North
A dark, deep crimson, rests a sea of blood,
Untroubled by a wave. And over all
Bendeth a luminous arch of pale, pure white,
Clearly contrasted with the blue above,
And the dark red beneath it. Glorious!
How like a pathway of the Shining Ones,
The pure and beautiful intelligences
Who minister in Heaven, and offer up
Their praise as incense;—or like that which rose
Before the pilgrim Prophet, when the tread
Of the most holy angels brighten'd it,
And in his dream the haunted sleeper saw
The ascending and descending of the blest!

And yet another change! O'er half the sky
A long, bright flame is trembling like the sword
Of the great angel at the guarded gate

Of Paradise, when all the holy streams
And beautiful bowers of Eden land blush'd red
Beneath its awful waving, and the eyes
Of the lone outcasts quailed before its glare,
As from the immediate questioning of God.

And men are gazing to these "signs in Heaven"
With most unwonted earnestness; and fair
And beautiful brows are redd'ning in the light
Of this strange vision of the upper air:
Even as the dwellers of Jerusalem,
Beleaguer'd by the Roman,— when the skies
Of Palestine were thronged with fiery shapes,
And from Antonia's tower the mailed Jew
Saw his own image pictured in the air
Contending with the heathen; and the priest
Beside the temple's altar veiled his face
From that fire-written language of the sky.

Oh, God of mystery! these fires are thine!
Thy breath hath kindled them, and there they burn,
Amid the permanent glory of Thy heavens,
That earliest revelation, written out
In starry language, visible to all,
Lifting unto Thyself the heavy eyes
Of the down looking spirits of the earth!
The Indian leaning on his hunting bow,
Where the ice mountains hem the frozen pole,
And the hoar architect of Winter piles
With tireless hand his snowy pyramids,
Looks upward in deep awe — while all around
The eternal ices kindle with the hues
Which tremble on their gleaming pinnacles,
And sharp, cold ridges of enduring frost,—
And points his child to the Great Spirit's fire.

Alas! for us who boast of deeper lore,
If, in the maze of our vague theories,
Our speculations, and our restless aim
To search the secret, and familiarise
The awful things of nature, we forget
To own Thy presence in Thy mysteries!

THE WORLD.

PART III.

PHYSICAL STRUCTURE OF THE EARTH.

CHAPTER 1.

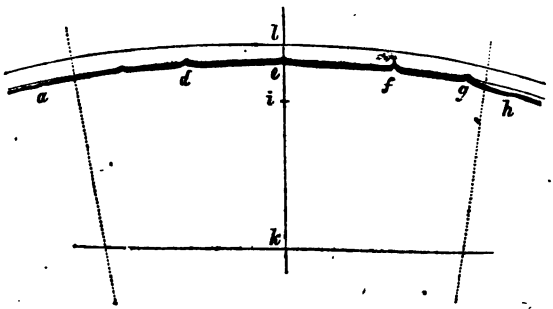
Structure of the Earth.

"Ye mighty ones who sway the souls that go
Amid the marvels of the world below!
Ye, silent shades, who sit and hear around!
Chaos! and streams that burn beneath the ground!
All, all forgive, if by your converse stirred,
My lips shall utter what my ears have heard;
If I shall speak of things of doubtful birth,
Deep sunk in darkness, as deep sunk in earth."

Virgil.

We have before shown that our globe is a planetary orb of a few thousand miles in diameter, and of a sphereidal shape, the difference between the polar, and equatorial diameters being twenty-six miles. The mean density of the earth, is about five times that of water, the interior being double that of the solid superficial crust, hence if the interior of the earth be cavernous, its crust must be composed of very dense materials. The crust, or outer covering of the earth, significantly called "*Erdrinde*," or Earth-rind, by the Germans, is that part to which our investigations are naturally directed. The greatest thickness of this superficial crust, which man has been able to explore, estimated from the highest mountain peaks, to the greatest natural or artificial depths, does not exceed ten miles; this, in comparison with the diameter, 8000 miles, is a distance, utterly insignificant, bear-

ing about the same relative proportion, as the thickness of this paper to an artificial sphere a foot in diameter. The inequalities and crevices in the varnish of such a sphere, would proportionately represent the highest mountains, and deepest valleys. In the following diagram, from the Penny Cyclopedia, the relative proportions of the crust of the earth, and the inequalities of its surface, as compared with the mass of our planet, are attempted to be shown.



The line from *e* to *k*, represents a depth of 500 miles, to the point *i*, a depth of 100 miles, and to the line *b*, 45 miles above the surface, the supposed limit of the earth's atmosphere. The dark line represents a thickness of ten miles, the estimated thickness of the crust of the earth; the points *d e f g*, indicate the altitudes of the highest mountains in the world. The highest peak in Europe, being Mont Blanc, which is 15,660 feet above the level of the sea; and in America, Mount Sorata, Andes, 25,400 feet, and in Asia, Chumularee, Himalayah, estimated at 29,000 feet, being more than five miles of perpendicular altitude. The depth of the sea is shown by the line *a h*, at the extremity of the arc. When we consider that the altitude of the highest mountains bears so small a proportion to the probable thickness of the earth's crust, we will be prepared to admit the possibility that they might once have been the bed of the ocean, and may have been raised to their present situations by subterranean agency,

The external crust, or covering of the earth, is composed of a vast amount of substances which we shall more fully describe hereafter, but which, under the indefinite but convenient terms of rocks and earth, embracing every variety of element, and combination, are familiar to every one. Although of such microscopic value as regards the dimensions of the globe itself, yet the crust upon which we are located, is of infinite importance to man. With its alternations of land and water, of valleys and mountains, it is the seat of vast empires, and the storehouse of the wealth of nations. The surface of the earth has been computed to contain one hundred and fifty millions of square miles, about three-fourths of which are covered by seas, and another large proportion by bodies of fresh water, by polar ice, and eternal snows; so that, taking into the estimate the sterile tracts, the forests, the barren mountains, the bogs, morasses, &c., scarcely more than one-fifth of the globe is fit for the habitation of man. The area of the Pacific ocean alone, is estimated as equal to the whole surface of the dry land, hence, if the waters of the globe were uniformly distributed over its surface, the inequalities being leveled, the whole earth would be covered with water to a depth of about three feet. The present arrangement of continents and islands cannot therefore be supposed to have always existed, indeed, there is abundant evidence to show that all those parts, which we call dry land, have at some very remote period been under water, and that the soil upon which we now tread, is composed of regular strata, deposited by water. It is but a short period since the utmost ignorance prevailed as to the structure of the planet which we inhabit. It was accustomed to be looked upon as a mass of confusion, the chaos of old, where, in incongruous masses, were heaped the various substances of which it was composed, and where antagonistic forces were striving confusedly together.

It was true that rocks were found at some places upon the surface, and not at others, but this was regarded as mere matter of chance, no one supposed any order, or any definite arrangement. It was reserved for modern science to show that the crust of the earth from its surface downwards, is composed of regular stra-

a, always succeeding in the same order wherever examined, and each formation marking a distinct epoch in the history of our planet; each characterized by its own flora and fauna, so that the whole substance which has hitherto been explored, consists of either minerals, i. e. inorganic substances formed by natural operations, or the fossil remains of animals and vegetables, characterizing peculiar and distinct epochs in the history of the globe. "The arrangement of the various formations may be represented by an alphabetical series from *a* to *z*, and this order, though it is frequently imperfect, is never inverted. We often miss one, or more, terms in the series, and lose, say the *b* or *k* or *m*, or even several letters in succession, but we never find the *b* taking the place of the *a*, or *d* preceding the *c*, or any member of the series usurping the position of another which ought to go before it; in other terms, we never meet with the entire series of deposits, but those which do occur invariably follow in a regular order of sequence."

We have said that these strata are all either mineral or fossil. Remotely they all are of mineral origin, for all organic substances have been at some time elaborated from inorganic matter by that marvelous principle termed vitality. There are fourteen simple substances which are named below in order, according to their importance, which constitute the chief part of the earth's surface. The first eight are called *simple Non-Metallic substances.*

1. Oxygen,
2. Hydrogen,
3. Nitrogen,
4. Carbon,
5. Sulphur,
6. Chlorine,
7. Fluorine,
8. Phosphorus.

These eight simple substances by their union with certain metals, which are hence called metallic bases, and also by union with each other, form by far the greatest amount of all the matter, organic, or inorganic, solid, or liquid, or gasseous, which is known to exist on the surface of the earth. The metallic bases alluded to are.

1. Silicium,
2. Aluminium,
3. Potassium,
4. Sodium,
5. Magnesium,
6. Calcium.

We cannot here describe each of these elementary bodies, this

will be found in most treatises upon chemistry; suffice it that a union of silicium and oxygen forms nearly one half the solid part of the earth's crust, being a chief ingredient in all the principal rocks. It appears nearly pure in the state of transparent rock crystal, and is the chief ingredient of our ordinary flints and sands. Aluminium in combination with oxygen, is the base of the various clays and clayey slates. Potassium in combination with oxygen, and also sodium with oxygen, constitute very important ingredients of the rocks and earths under the well known forms of potash and soda, and the latter in combination with chlorine forms muriate of soda or common salt, so widely prevalent in the ocean, and in beds of rock salt. Magnesium is the base of manganese a chief ingredient of the chalks, and magnesian limestones; and calcium is the metallic base of lime, and is found in abundance in the various limestones and gypsums. Besides the simple substances named, we have the metallic minerals, which are usually found in beds or veins. The most of these are so well known that they are recognised at a glance. Iron is the most useful and most abundant, when combined with sulphur it crystalises in cubes, is of a bright yellow, and is often mistaken for gold; this variety is termed iron pyrites. Iron is likewise found in combination with oxygen and carbon, and occasionally nearly pure. Lead is a well known metal occurring principally in union with sulphur, under the form called galena, in cubic crystals. Copper is found in combination with oxygen and sulphur, and also native, or pure; in combination with carbon and oxygen it assumes beautiful tints of blue and green. Tin, zinc, and manganese are too well known to need any particular description here. It is said that tin is only found in the primitive or lowest order of rocks, and that the tin mines of Cornwall extend many hundred feet under the sea, and that the noise of the waves and the rolling of the pebbles can be distinctly heard. We need not describe the precious metals, silver, gold, and platina, as everybody is familiar with their general properties. The various substances which form the crust of the earth, and which have been investigated by the persevering energy of man, are arranged into two great classes, which embrace all the various soils, sands,

gravels, clays, limestones, coals, slates, and granites; these two classes, are the *stratified*, and *unstratified* rocks. In the former, are included those portions of the crust of the earth which exhibit a sedimentary character, *i. e.*, evidence of deposition through the agency of water. It is supposed that all rocks were once deposited in this manner, but that the present crystaline form of some of them is owing to heat, hence the unstratified, are sometimes termed the *igneous* or the *plutonic* rocks; and the strata which happen to intervene between them, being partly changed in their character, yet not wholly so, are termed the *metamorphic*, or transformed rocks; and those rocks resembling lavas, scoriæ, and other substances, emitted by burning mountains, still in activity, are called *volcanic*. When we assume that all the igneous or plutonic rocks, such as granite, sienite, and the like, are of sedimentary origin, we speak hypothetically, they are supposed to be so; for rocks, which are well known to present evidence of aqueous origin, become crystaline, and lose the marks of stratification under pressure, and by the influence of heat; thus, chalk has been converted into marble. Sir James Hall, exposed pounded chalk to intense heat, under great pressure, and it was fused, not into lime, but into crystaline marble; even the shells inclosed in the chalk underwent the same transmutation, yet preserved their forms; and where ancient streams of lava have traversed chalk, the latter invariably possesses a crystaline structure, and a series of changes from a loose earthy deposit, to compact volcanic lava, may be traced in numerous instances, so as to leave no doubt of the former aqueous origin, and the sedimentary deposit.

The crystaline rocks, such as granite, sienite, porphyry, serpentine, and greenstone, are generally termed the ancient or earliest rocks, as they are uniformly found underlying all the other strata; they were hence, named *hypogene*, under-lying, by Mr. Lyell. It is now however, ascertained that they belong to no particular age or epoch, exclusively; for granite is found occurring at comparatively modern, as well as ancient epochs, overlaying the other strata precisely in the same manner as masses of volcanic rock recently ejected, spread out upon the soil below. The difference in character between the modern lavas, and

the lower igneous rocks, is doubtless to be attributed to their formation upon the surface, instead of under pressure. The term hypogene includes the plutonic, and metamorphic rocks.

The sedimentary rocks are termed fossiliferous, or fossil-bearing, in distinction to the igneous, or plutonic rocks, in which, by the action of heat, all fossil remains are wanting. The stratified rocks were originally deposited in a horizontal position as represented in this engraving, but they are rarely seen perfectly hori-

zontal, hence, it is inferred, that subsequently to their deposition, they have been subjected to a variety of disturbing causes, by which they have been made to assume all inclinations to the horizon. Occasionally they are uplifted to an almost vertical position, as in the following illustration, exhibiting the strata on which Powis Castle is built; when by being thus upheaved, the

edges of the strata are denuded, or uncovered, they are said to crop out, when this occurs, it will be found that the strata succeed each other in regular order, as we have already mentioned. When strata crop out, it is apparent, that having been elevated by

some internal agency, the various *formations*, or beds of nearly the same character, will occur in contrary order, thus, suppose that by an upheaving cause, a series of strata, fig. 1, lying orig-

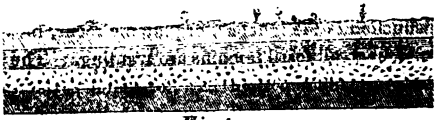


Fig. 1

inally horizontal, as deposited at successive epochs, by water, to be, by some internal force, upheaved as in fig. 2, the external

Fig. 2

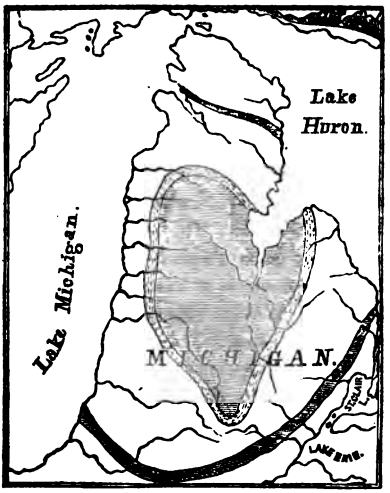
surface being rent and cracked, and further that after a course of ages, the softer and more modern deposits should be worn away by the agency of rains, frosts, floods, &c., until it was reduced to the level *a b*, we would have the succession of strata as in fig. 3,

Fig. 3

the harder rocks, perhaps of granite, forming a nucleus, or centre, around which the rest would lie in order; perfectly circular if the elevation had been a true mound, or arranged in lines parallel, or curved, according to the nature of the original elevation, and if the elevation and subsequent denudation, had occured at a very remote period, the whole might be covered with a light loose soil. A very pretty and instructive example is shown in the diagram on the next page, which is an outline map of Michigan.

Here the centre of the state is occupied by the coal measures or formation, shown by the shaded portions, skirting this i a narrow stratum of limestone, beyond this and circling around it, is a

wide stratum of the sandstone formation, followed by a formation of marine limestone and shales and slate. It is by observations



thus made near, or upon the surface, and carefully compared by means of the fossils which are found imbeded in them, that geologists classify the various groups in the order we shall presently name, and, as each stratum is characterized by its peculiar fossils, and is never found taking the precedence of another which may be anywhere found before it, they are justly supposed to be the productions of different epochs. Thus, at one period of the earth's history, peculiar limestones, sandstones, marls, and clays, were deposited over the whole globe, upon those portions covered by water; in which the zoophytes, fishes, drifted wood, plants, reptiles &c., characteristic of that epoch were imbedded. At another and previous period, were deposited the shales, the millstone grit, and the immense beds of coal, imbedding peculiar and distinct remains of animals and vegetables characteristic of that epoch. At a still earlier period we find other distinct sedimentary rocks, and under the whole, although sometimes appearing on the

surface, by being upheaved and uncovered, are found the crystaline masses of granite, porphyry, and sienite. Above all these well marked sedimentary, or water deposits, lies a vast accumulation of what is termed drift, being water worn, transported materials, consisting of the ruins of older rocks, and forming our light covering soil, sometimes scarcely overlaying, and at others of many feet in thickness, principally sand, clay, and gravel, and large masses of water worn or rounded stones, called boulders. The more recent deposit of this sort is called Alluvium, and in it are imbedded the remains of man and his works, and such is the character of the fluviatile or river deposits now going on, and to which we shall again allude. The older deposit is termed Diluvium, and is found to contain no traces of man or his works, but in it are imbeded the remains of huge animals and reptiles now extinct, and also with them the bones of many existing species of animals, and the fossil remains of many known species of plants are found. In the following chapter we shall endeavor to give a clear view of the succession of the various strata and a short description of each, which shall be intelligible to any one who may feel enough interested to read it, and in concluding this chapter we must be allowed to say, that if the present part of our work does not interest the reader, the book may as well be closed; we can learn him nothing, for there is no sympathy between us.

CHAPTER II.

Chronological Arrangement of Strata.

"What once had been the solid earth, I saw
To be a strait; and from the waves new lands
Arose. Far off from the resounding sea,
The shells were strown about." *Ovid.*

ALTHOUGH geologists are perfectly agreed as to the order of succession of the various strata, yet they have different methods of expressing the same fact. In other words, the names which are used to designate the different formations vary somewhat, but in the great leading features all are agreed. Thus, it matters little, whether, after having divided all rocks into two great classes, fossiliferous, and non-fossiliferous or metamorphic, we subdivide the former with Dr. Buckland, into alluvium, diluvium, tertiary, and the secondary or transition series; or with Dr. Mantell, into modern and ancient alluvium, tertiary strata, and secondary formations; both include the same classes of rocks; or whether we name a certain order of rocks the saliferous strata, or the upper and lower red sandstone; both mean the same thing. The classification which we have adopted is principally that of Dr. Mantell, who gives the following as the chronological arrangement of the strata, commencing with the uppermost or newest deposits.

I. FOSSILIFEROUS STRATA.

1. MODERN AND ANCIENT ALLUVIUM.—Comprising the modern and superficial deposits of waterworn and transported materials, sometimes called drift, and consisting of gravel, boulders, sand, clay, &c. The *modern* deposits are characterized by the remains of man, and contemporaneous animals and plants. The *ancient*, sometimes called *Diluvium*, by an immense proportion of large

mammalia and carnivora of species and genera, both recent and extinct.

2. THE TERTIARY SYSTEM.—An extensive series comprising many isolated groups of marine, and lacustrine, or lake formed deposits, characterized by the remains of animals and vegetables, the greater portion of which are extinct. Volcanoes of great extent were in activity during this epoch. Mr. Lyell subdivides this series into the *pliocene*, or more recent; the *miocene*, less recent; and the *eocene*, dawn of recent; according to the percentage of recent shells contained in each.

Secondary Formations.

3. THE CHALK OR CRETACEOUS SYSTEM.—A marine formation, being the bed of an ancient sea, comprising limestones, sandstones, marls, and clays, and abounding in the remains of zoophytes, molusca, cephalapoda, fishes &c., drifted wood, and marine plants, with crocodiles, turtles and other, now extinct reptiles, also birds.

The chalk formation embraces several beds or distinct strata, thus, we have the upper chalk with flints, and the lower without; the chalk marl, the firestone, the galt or stiff blue, or black clay, abounding in shells, the shanklin or green sand.

4. THE WEALDEN.—From the German *wald*, a wood, the whole tract so called in England having been once a dense forest. This formation is the only known secondary fluviatile, or river formed deposit. It is a fresh water formation, evidently the deposit of some enormous ancient rivers, its fossil remains being the spoils of river and land, it is characterized by the remains of enormous and peculiar reptiles, namely the iguanodon, hylaeosaurus, megalosaurus, plesiosaurus, crocodile, turtle, &c.; of terrestrial plants, fresh water shell-fish, and birds. The group called the Wealden is composed of beds of stiff blue clay, with beds of shelly limestone, called Sussex marble, beds of sands and sandstones as found at Hastings in England, and the clays, sandstones, and shelly limestones, as found in the Isle of Purbeck, called Purbeck marble.

5. The Oolite.—This is a marine formation of vast extent and thickness, its name means egg stone, because, it is formed of small egg like grains. It consists of limestones and clays, which abound in marine shells, corals, fishes; reptiles, both terrestrial and marine; land plants of peculiar species, and the remains of two or more genera of marsupial animals, are likewise found in it.

6. The Lias.—This name is supposed to be a provincial corruption of the word layers, as it consists of shale, or indurated slaty clay, which splits into layers, alternating with clays and limestones, containing marine shells, cephalapoda, crinoidea and fishes. It is chiefly remarkable however, for its remains of enormous reptiles particularly the plesiosaurus and the ichthyosaurus. The Lias group consists of the upper lias shale, mixed with the lower oolite, containing saurian remains, belemnites and ammonites; the lias marls; calcareous, sandy, and ferruginous; the lower lias clay and shales intercalated with sands and septaria, and lastly a series of laminated limestones, with partings of clay, which change into vast beds of red marl and sandstone forming,

7. The Saliferous, or New Red Sandstone System.—A marine formation comprising variegated marls and sandstones, and conglomerates, frequently of a red color. The name *new* is given to distinguish it from a formation of the same mineralogical character but much older. This series of deposits is remarkable for the traces or footsteps of marsupial animals, and birds, and contains fossil remains of marine and terrestrial plants, fishes and reptiles. This series forms the grand depository of rock-salt and lime, hence called the saliferous, *salt bearing*. Its variegated color is owing to oxide of iron. The series consists of the upper new red sandstone, containing gypsum and rock salt, with variegated red and white sandstones, conglomerates or detritus of older rocks cemented together, and the lower new red sandstone, consisting of magnesian limestones called dolomite, and marls and conglomerates colored with oxide of iron. This series rests upon,

8. THE CARBONIFEROUS, OR COAL SYSTEM, which is formed of sandstones, grits, shales, layers of ironstone, and clay; with immense beds of coal; fresh water limestone sparingly, and marine limestone abundantly. This system is characterized by innumerable remains of land and aquatic plants, of a tropical character, and belonging to extinct species and genera, with fishes, reptiles, and insects. The series includes the *coal measures*, which are sandstone, and shale, with numerous layers of coal, containing land plants in profusion. Limestones, with fresh water and marine shells, *Millstone grit*, which consists of sandstone and shale, with thin seams of coal, and quartose conglomerates sometimes used for millstones. *The carboniferous or mountain limestone*, consisting of limestone and flagstone, abounding in crinoidea, and marine shells, yielding several varieties of black, blueish grey, and variegated marbles. The coal bearing strata of this country differ some from the European. The seams of coal appear however, even in Europe, to be very unequally distributed; although the great coal formation belongs in the order where we have placed it, yet seams of anthracite coal are found in almost every rock from the lias, to the upper metamorphic rocks, showing that the coal beds have occurred at very unequal intervals, hence their formation may be of any date between the new and the old red sandstone.

9. THE DEVONIAN, OR OLD RED SANDSTONE SYSTEM.—This name is derived from the English locality, where it is most largely developed, viz: Devonshire. It is a marine deposit, chiefly remarkable for its extraordinary forms of fossil fish. This system is composed of various strata, flagstones, conglomerates, quartose grits, sandstones, marls, and limestones; the prevailing color of all these is a dark red. But few fossils are found in the sandstone and conglomerates, but in the marls, and concretionary limestones, sometimes called *corn-stones*, peculiar genera of fish, and many species of marine shells are found. This system lies immediately below the mountain limestone. The sandstones are in various stages of induration, and when slaty are employed for roofing. The red color is derived from peroxide of iron. The formation of these rocks, has manifestly resulted from the waste

of slate rocks, their detritus being cemented together by red sand, or marl, into coarse conglomerates.

Primary Fossiliferous Period.

10. The Silurian System.—This name is derived from *silures*, the name of the ancient Britons who inhabited that part of England where it is most developed, viz: the border counties of England and Wales, and south Wales. It is a marine deposit of vast extent and importance, containing a great abundance of organic remains. It is principally composed of marine limestone, shales, sandstones, and calcareous flags, abounding in shells, corals, trilobites, and crinoidea of peculiar types; but few vegetable remains are found below the old red sandstone.

11. The Cambrian, or Grauwacke System.—Grauwacke is a coarse slaty rock, containing fragments of other rocks, sometimes passing into the common clay slate, and sometimes, when the fragments are very numerous and small, into sandstones and grits; it contains a few shells and corals, and occasionally impressions of fuci; with this system all traces of organic remains disappear. The fineness of grain, general aspect, and character of these rocks, are well known from the universal employment of slate for economic purposes.

II. HYPOGENE OR METAMORPHIC ROCKS.

Destitute of Organic Remains.

STRATIFIED.

12. The Mica Schist.—This formation is supposed from certain traces of stratification, to have been sedimentary in its origin, but subsequently altered by the influence of heat. It consists of mica slate, granite rock, crystaline limestone, or white marble, and hornblende schist, exhibiting no traces of organic remains.

13. The Gneiss System.—Layers of gneiss, sienite, and quartz rock, alternating with clay slate, and mica schist, but still exhibiting marks of former stratification.

UNSTRATIFIED.

14. Granitic System.—Consisting of porphyry, serpentine, and trap rock in shapeless masses, and in dykes and veins.

15. VOLCANIC ROCKS.—These are the products of fire, or subterraneous heat, ejected from beneath the surface, through fissures in the earth's crust, both in ancient and modern times. The erupted materials of the ancient volcanoes being *trap, basalt, toadstone and tuff*, and the products of recent sub-aerial volcanoes, lava, scoriae,, *pumice and ashes.*

The general proportionate thickness of each of these several deposits has been estimated as under, but the statement must be regarded as a mere approximation.

Tertiary System,	2,000	feet.
Cretaceous,	1,000	"
Weald,	1,000	"
Oolite and Lias,	2,500	"
Saliferous,	2,000	"
Carboniferous,	10,000	"
Old Red Sandstone,	10,000	"
Silurian,	7,500	"
Cambrian,	30,000	"

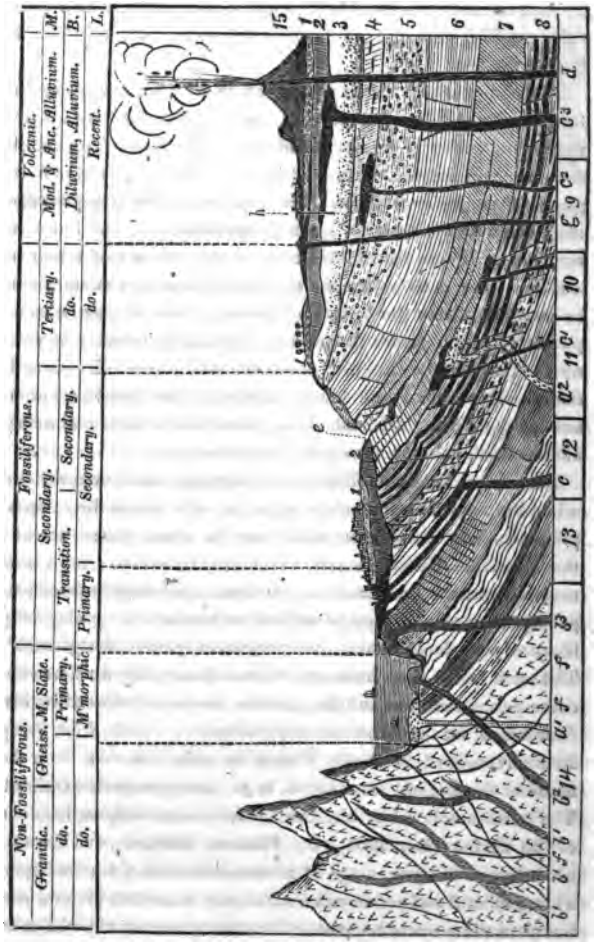
Mica Schist, and Gneiss, not ascertained, but far exceeding that of any of the superposed deposits.

We have now given a connected view of the order of succession of the several strata, each characterised by its peculiar animals and plants. All these are marine deposits except one, the fourth, called the Wealden. This is a fresh water formation, and is the deposit of a mighty ancient river, or of several of them, and its organic remains are such as might be expected to result from the sediment of such a river, consisting of plants, shells, fish, and reptiles, imbedded in the mud together. It is almost the only evidence which remains of the ancient land, showing that while the immense deposits were going on in the bed of the ocean, here were bodies of fresh water, rolling over a vast extent of land, bearing upon their waters the remains of trees, and huge reptiles. In the following chapters we shall consider each of these formations more fully, and describe more particularly some of the fossils found in them. It will be observed by the careful reader, that most of the marine deposits of the several epochs have the same mineralogical character: if we except the coal, we will find the rest alternating with marls, clays, limestones, and sandstones; each being formed from the ruins of

more ancient formations, and each, imbedding in its sediment the characteristic shells, fishes, reptiles, and plants, which were either washed into, or once lived in the ancient sea, of which it formed the bed.

The names which have been given to the different geological formations must be received with some caution, for they are not always indicative of formations identical with those from which the name was derived. Many of these names are borrowed from places; thus, we read of the Jura limestone, the Kimmeredge clay, Oxford clay, Purbeck marble, Portland rock, and Potsdam sandstone. These names, referring to the stratum of a known locality, were good so far as an identity with that stratum can be traced, but from the nature of the case, this is often incompletely done, and hence the names necessarily cease to be definite. Many of the English provincial names are still retained, though very uncouth and harsh sounding, thus Geologists often employ the terms Cornbrash, Lias, Gault, Coral Rag, and many others which have no systematic signification.

Descriptive names applied in Geology are also defective, and when employed, no scrupulous regard must be had to their appropriateness. "The *Green Sand* may be white, brown, or red; the *Mountain Limestone* may occur only in valleys; the *Oolite* may have no roe-like structure; and yet these may be excellent geological names, if they be applied to formations, geologically identical with those which the phrases originally designated." The term *Oolite* is an instance where a descriptive word has become permanent, and in like manner the term proposed by Mr. Murchison, for the transition series of rocks, which, from being distinctly marked in South Wales, he calls *Silurian*, from the name of the ancient inhabitants, is in many respects excellent. The terms employed by Mr. Lyell, before mentioned, as divisions of the Tertiary formation, viz: *Pliocene*, *Miocene*, and *Eocene*, according to the percentage of recent shells, being founded upon a more natural distinction will undoubtedly come into general use, but even these are to be used with caution, and not allowed to set aside the indications drawn from the natural relations of the strata.


Non-Fossiliferous.
Fossiliferous.
Volcanic.
Granitic.
Gneiss. M. Slate.
Secondary.
Tertiary.
Mod. & Anc. Alluvium.
M.
do.
Primary.
Transition.
Secondary.
do.
Diluvium, Alluvium.
B.
do.
M'morphic
Primary.
Secondary.
do.
Recent.
L.

EXPLANATION.

Ideal section of the crust of the earth, showing the chronological arrangement of the strata.

M—Mantell.

B—Buckland.

L—Lyell.

1. Alluvial or modern deposits.
2. Tertiary formations.
3. Cretaceous system, comprising the chalk, with & without flints, chalk marl, galt or blue clay, Shanklin sand.
4. The Wealden.
5. The Oolite.
6. The Lias.
7. The Saliferous, consisting of New Red Sandstone, Magnesian Limestone.
8. The Carboniferous System, namely, the Coal measures, the Mountain limestone.
9. The Devonian, or Old Red Sandstone.
10. The Silurian, consisting of marine limestones, shales, calcareous flags.
11. The Cambrian.
12. Mica Schist.
13. The Gneiss.
14. Granitic System.
15. Volcanic Rock.

a. 1. Dyke of Porphyry in granite, passing through & overlaying gneiss.

a. 2. do. do. Overlaying the coal formation.

b. 1. Granite veins in Granite.

b. 2. do. do. passing through porphyry, gneiss, & mica schist.

b. 3. do. do. Overlaying Grauwacke.

c. Dyke of Trap, passing thro' grauwacke and the laminations of marine limestones, forming basaltic columns.

c. 1. do. do. intersecting, and overlaying an older dyke of porphyry.

c. 2. do. do. overlaying the oolite system.

c. 3. do. do. overlaying the chalk being lava of the extinct volcanoes of the Tertiary period.

d. Modern lava.

e. Cave in magnesian limestone.

f. Metallic veins in granite.

g. Extinct volcano.

h. Artesian well.

The order of succession which we have given has been determined by a series of the most patient investigations, and from an immense accumulation of facts, collected by able observers in all parts of the globe. On page 194 we have given a diagram showing their order. It will be perceived that some parts of the representation are necessarily exaggerated. Commencing at the left we have the hypogene, or underlying rocks, unstratified and stratified; then the primary and secondary fossiliferous, and also the tertiary, lastly the volcanic. The alluvium we have placed in various situations, overlaying the older rocks.

CHAPTER III.

Aqueous Causes of Change.

"The rivers swell,
Of bonds impatient. Sudden from the hills,
O'er rocks and woods, in broad, brown cataracts,
A thousand snow-fed torrents shoot at once;
And where they rush, the wide resounding plain
Is left one slimy waste." *Thomson.*

In the preceding chapter we have given a general view of the arrangement of the strata which compose the crust of the earth. We now proceed to consider the changes at present going on in the organic and inorganic kingdoms of nature. We will thus be better prepared to admit that the fossil remains which occur everywhere in the stratified rocks, and that the stratification of those rocks, are results of laws now in full operation, but exerted through a period of years, it would be utterly vain to attempt to estimate. In the present chapter, which presents us with a subject which of itself might form a volume, we can only hastily glance, at some of the most active causes of change now in operation, those who desire to learn more will find ample information in the writings of Lyell, Mantell, Buckland, and other well known geologists.

Although from the very nature of the case, geology is somewhat a speculative science, since it takes into consideration the changes and vicissitudes which the earth has undergone, during ages so remote, that the mind can with difficulty conceive of the lapse of time past, and endeavors to explain them by the application of laws now in action, but whose silent operation is unheeded by the great mass, yet it at the same time presents us with the noblest views of the material universe; and the philosophic mind, in reviewing ever so cursorily, the traces of the past, cannot fail to be struck with the harmony of the material world. Everything

around us is in a most active state of change, literally speaking there is no such thing as rest. Every operation of nature, however minute and familiar, the heat and the cold, the moisture and the drouth, the warmth of summer and the frosts of winter, the snow and the ice, nay, every drop of rain that falls from the atmosphere, performs its share in displacing and renewing the solid crust of the earth, and contributes its alloted portion in carrying on the great work of universal metamorphosis and change. The great agents of change in the inorganic world may be divided into two classes, the aqueous and the igneous. To the aqueous belong rivers, torrents, springs, currents, and tides; to the igneous volcanoes and earthquakes. Beside these we may enumerate the agency of the atmosphere, which is partly mechanical, and partly chemical; and vital action. We shall consider these several agents of change in order, and see their present effect in changing the sea to land, and land to sea; in excavating valleys and destroying hills; in the transition of dry ground to marshes, and the reverse; the occurrence of earthquakes and their phenomena; the uniting of islands with main lands, and insulation of peninsulas.

In this manner, although we may not be able to comprehend entirely the degrading and elevating causes above enumerated, yet we will see abundant means for the conversion of the soil upon which we now tread, from the bed of an ocean to dry land; we shall see how wood has been changed into stone, and plants and fishes imbedded in solid rock. We shall first consider the action of running water. The heated atmosphere which sweeps over the vast ocean and the surface of the earth, absorbs and carries with it an immense amount of aqueous vapor, to be again deposited when the air is cooled, in the form of clouds, mist or rain. A large amount of this moisture is deposited upon mountains and elevated lands, and thus the more elevated regions become perpetual reservoirs of water, which flows down in gentle streams and rivers, irrigating the plains below. At the first glance we might suppose the amount of water carried up into the air by evaporation was of too trifling a nature to be instrumental in effecting any great mechanical change, but a moments reflection

will convince us that the amount is almost beyond estimate. All the rivers on the face of the earth are constantly pouring their waters into the sea, and yet its level is not affected in the slightest degree, hence we infer that the quantity of moisture evaporated from the surface is exactly equal to the sum of all the rivers of the world. If the evaporation and restoration of the waters were all the effect which is produced by the agencies just described, little change would be accomplished upon the face of the country over which the waters might flow in their passage to the sea. But in the more elevated tracts of country, the atmosphere acts powerfully upon the soil, and by the influence of heat and cold, by dampness and dryness, and of frost and rain, loosens the most coherent masses and disintegrates the solid rocks. The mountain streams flow down more or less charged with earthy matter, worn from the soil and rocks over which they flow. In their passages toward the sea, sometimes over an immense tract of country, they often unite and pour their waters along with almost irresistible fury. The solvent power of the water assists very materially in degrading the rocky channels through which it flows, and acts powerfully on the alkaline and calcareous elements of the soil, and especially when it holds carbonic acid in solution, which is almost always the case. When the earthy matter and pebbles are thus intermingled with running water, a new mechanical power is gained, by the attrition as they are borne along, thus sapping and gradually undermining high banks and rocks, until at length the overhanging mass is precipitated into the current and swept away by its waters. In this manner, islands are cut off from the main lands, and shoals, and rich earthy deposits called deltas are formed at the mouths of rivers. There is nothing so very remarkable in the power of currents to transport even heavy masses of stone, for we must remember that the specific gravity of water is much greater than air, and a stone immersed in a stream will loose about half its weight, and many of the lighter particles of the soil will almost float.

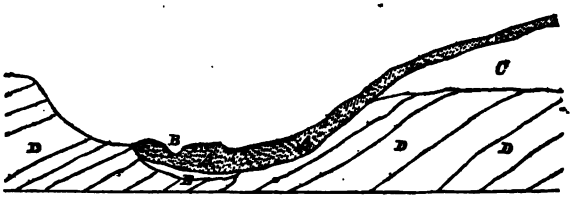
Sir George Staunton estimated that the quantity of sediment borne down by the Yellow River in China, in a single day, was equal to forty-eight millions of cubic feet, and late observations

upon the Ganges, at the time of its flood, or in the rainy season, when it is fully charged with sediment, shows that it discharges 6,082,041,600 cubic feet in 122 days, and during the three months of hot weather, and the five months winter, it discharges 286,035,840 cubic feet more, a quantity small compared with the former, the total annual discharge is therefore 6,368,077,440 cubic feet.

"In order" says Mr. Lyell, "to give some idea of the magnitude of this result, we will assume that the specific gravity of the dried mud, is only one-half that of granite (it would, however, be more), in that case the earthy matter discharged in a year, would equal 3,184,038,720 cubic feet of granite. Now, about 12½ cubic feet of granite weigh one ton, and it is computed that the great Pyramid of Egypt, if it were a solid mass of granite, would weigh about 6,000,000 tons. The mass of matter therefore carried down annually, would, according to this estimate, more than equal in weight and bulk forty-two of the great pyramids of Egypt, and that borne down in four months of the rains, would equal forty pyramids. The base of the great Pyramid of Egypt covers eleven acres, and its perpendicular height is about five hundred feet. It is scarcely possible to present any picture to the mind which will convey an adequate conception of the mighty scale of this operation, so tranquilly and almost insensibly carried on by the Ganges. It may however, be stated, that if a fleet of more than eighty Indiamen, each freighted with about 1400 tons weight of mud, were to sail down the river every hour of every day and night for four months continually, they would only transport from the higher country to the sea, a mass of solid matter equal to that borne down by the Ganges in the flood season."

The same effect is observable in the mighty rivers of America. The Mississippi annually bears down upon its swollen stream innumerable quantities of trees and sediment, which are imbedded in the basin of the sea at the mouth of the river. In this manner the remains of animals and vegetables are being continually enveloped, and, should these deltas some day become dry land, the naturalist could determine by a study of the imbedded remains,

the character of the country through which the stream had flowed. Below we give a diagram showing the excavation of a lava current by the action of the river Simento, one of the largest of the



Sicilian rivers, which flows at the base of Etna. A A, bed of lava which has flown to a distance of five or six miles; B, bed of the Simento; C, foot of the cone of Etna; D, marine and volcanic strata; E, ancient bed of the river. The lava current in which the channel is eroded is one of the more recent, having been ejected in 1603. In a little more than two centuries the Simento has worn a passage from fifty, to several hundred feet wide, and in some parts from forty to fifty feet deep. The portion of lava cut through, is not porous, or mixed with cinders and scoria, but consists of a compact homogeneous mass of hard blue rock. The Falls of Niagara afford a magnificent example of the progressive excavation of a deep valley in solid rock. It appears from examination that the Falls were once at Queenstown, about seven miles below their present position. It is possible however that a natural chasm may have previously been formed a part of this distance, which the river has since widened, although a careful study of the face of the country, and also the existing proofs, at various places, several miles below the present falls, of fluvatile deposits, seem to show conclusively that the falls have gradually receded from near the present site of Lewiston and Queenstown.

When by the melting of snows and ice, an unusual amount of water is accumulated at some high point, and the barriers which have been restraining it give way suddenly, the flood sweeps onward with a fury which overcomes every obstacle. Such was the flood in the valley of Bagnes, described by Mr. Lyell, in his Principles of Geology. The bed of the river Dranse being blocked

up by the avalanches of snow and ice, a reservoir or lake, was thus formed, about half a league in length, two hundred feet deep, and seven hundred feet wide. To lessen the mischief apprehended from the sudden bursting of this ice barrier, a channel was cut through the ice about 700 feet in length; the flow of the waters deepened this channel until nearly half the contents of the lake were drained off, but on the approach of the hot season, the remaining mass gave way with a tremendous crash, and the residue of the lake was emptied in half an hour. As the mass of waters and floating ice swept through the narrow gorges, it rose sometimes to an immense height, to burst again with increased fury into the next basin, sweeping along rocks, forests, bridges, and cultivated lands. Immense fragments of granite rock were torn from the ancient soil and borne down; one of these, was sixty paces in circumference.

The Deltas, or triangular sedimentary deposits which are formed at the mouths of large rivers, often exhibit distinct marks of stratification, and when they terminate in an extensive estuary, or arm of the sea, the layer of mud brought down by the river is regularly covered by a layer of sand, borne in and deposited upon the mud at each returning tide. It is in this manner that the ripple marks, and tracks of vermes, and molusces, are preserved. Every one must have noticed, in walking along a sandy shore, at low water, the undulating surface of the mud or sand, caused by the little ripples in the water, and also the varied tracks of worms, shell-fish, and birds. When a thin layer of mud happens to be deposited over these before the next return of the waves, a perfect cast is thus obtained. Mr. Lyell, in his travels in North America mentions that he had obtained at Wolfville, on the Bay of Fundy, thin slabs of the dried red mud, which presented perfect impressions, on the upper side, showing the recent foot-prints of a small sandpiper, as it marched over the soft mud, which had afterwards so much hardened in the sun as to become consolidated, and upon the under surface exhibiting a cast of the impressions made in a previous deposit. The red sediment, or mud deposited by the waters of the Bay, is obtained from undermining cliffs of red sandstone, and soft red marl, and whenever the velocity of the

current is suspended by the rush of the tides, this mud is thrown down, and very large, and widely extended tracts, of rich soil, have thus been formed, and thousands of acres have been excluded from the encroachments of the sea by artificial embankments. At the time of very low tides, this soft mud is sometimes exposed to the sun for several days, and thus becomes sufficiently baked or consolidated, to a depth of several inches, to resist the flow of water, which soon deposits upon it another thickness of mud. We shall see that in a precisely similar manner, footprints, of high antiquity, were formed in the strata of new red sandstone of the valley of the Connecticut, and also in Europe.

The large rivers which flow from south to north in the northern latitudes, having their sources in a much warmer latitude than their mouths, become swollen in their progress northward, on account of the ice which has not yet been broken up, hence they overflow and sweep through the forests of pines and birches, and carry away thousands of the uprooted trees. The timber thus drifted down is often laden with the earthy deposit around the roots, and being deeply sunk in the water, other masses become piled upon it until at length becoming water-logged it sinks and is imbedded in the strata if there be any forming. "As the trees" says Dr. Richardson, "retain their roots, which are often loaded with earth and stones, they readily sink, especially when water soaked; and, accumulating in the eddies, form shoals which ultimately augment into islands. A thicket of small willows covers the new formed island as soon as it appears above the water, and their fibrous roots serve to bind the whole firmly together. Sections of these islands are annually made by the river, assisted by frost, and it is interesting to study the diversity of appearances they present, according to their different ages. The trunks of the trees gradually decay until they are converted into a blackish brown substance, resembling peat, but which still retains more or less of the fibrous structure of the wood; and layers of this often alternate with layers of clay and sand, the whole being penetrated to the depth of four or five yards or more, by the long fibrous roots of the willows." A deposition of this kind, with the aid of a little infiltration of bituminous matter, would produce an excellent

imitation of coal, with vegetable impressions of the willow roots. We will close this chapter with a discription of those extensive accumulations of vegetable matter called peat bogs. These are marshy grounds covered with successive layers or beds of mosses, reeds, equisetæ, rushes, and other plants which affect a marshy soil; but a species of moss called *sphagnum palustre*, which has the peculiar property of throwing up new shoots in its upper part whilst the lower is decaying, forms a great part of the peat bogs of Europe. It is said that one-tenth of Ireland is covered by these marshy bogs, in which trees are often found standing erect, with their roots imbedded in the sub-soil; thus presenting evidence of the formation of the bog since the growth of the trees; these are generally oaks where the sub-soil is clay, and firs where it is sand. The peat bogs of the north of Europe occupy the areas of the ancient forests of oak and pine. At the bottom of peat bogs, cakes of oxide of iron, termed bog-iron ore are found, partly precipitated from mineral waters, and partly from the decaying vegetable masses.

One of the most remarkable facts connected with the peat bogs, is the preservation of the bodies of men and animals for an indefinite period of time; in many instances they are converted into a peculiar fatty substance, which resembles spermaceti, called *adipocire*. In June 1747, the body of a woman was found six feet deep in a peat-moor, in Lincolnshire. The antique sandals on her feet afforded evidence of her having been buried there for many ages; yet her nails, hair, and skin, are described as showing hardly any marks of decay. On the estates of the Earl of Moria in Ireland, a human body was dug up a foot deep in gravel, covered with eleven feet of moss; the body was completely clothed, and the garments seemed all to be made of hair. On the confines of England and Scotland, is a flat area, about seven miles in circumference, known as the Solway moss. It is a boggy ground covered with grass and rushes, presenting a dry crust and fair appearance, but it shakes under the least pressure, the bottom being unsound and semi-fluid. The adventurous passenger, who sometimes in dry seasons, traverses this perilous waste, to save a few miles, picks his cautious way over the rushy

tussocks as they appear before him, for here the soil is firmest. If his foot slip, or if he venture to desert this mark of security, it is possible he may never be heard of. In 1772 on the 16th of December, this moss being filled with water during heavy rains, burst, and a stream of black half-consolidated mud began to creep over the plain, it overwhelmed some cottages, and covered an area of 400 acres to a depth of fifteen feet. Dr. Jackson mentions that in the peat bogs of Maine, a substance exactly similar to cannel, or anthracite coal, is found amidst the remains of rotten logs of wood, and beaver sticks. It is a true bituminous coal, probably formed from the balsam-fir during its long immersion in the humid peat.

We have now briefly considered the action of rivers, and running waters, their effect in carrying down to the ocean or lake a vast quantity of sediment, which is finally deposited, and subquently, either by pressure, or exposure to air consolidated into rock; that large tracts of country called deltas, at the mouths of rivers, are in progress of formation, in which are buried the remains of animals and vegetables, and in which, are preserved the tracks of worms, molusces, and birds; that by collections of rafts upon the large rivers, laden with stones, earths, and sands, islands are forming, and the materials for future beds of coal collecting; that peat bogs are now growing, and, bursting their barriers, flooding whole tracts of country, and imbedding forests, and the habitations of men. By similar actions, exerted at the most remote periods, the present strata of the earth's crust were deposited, and the masses of limestones, sandstones, and shales, were formed. We are thus irresistably led to the conclusion, that however remote may have been the date of these formations, or however deep they may now be buried below the present surface, they were once exposed, and over their surface living things moved, and upon it lay the wrecks of organic matter.

The entire absence of human remains or works of art in the anciently formed deposits, and their extreme abundance in modern alluvium, is a sufficient proof of the comparatively recent origin of the human race. It cannot be doubted that human re-

mains are as capable of resisting decay as the harder parts of many inferior animals. Such remains however, except in places subject to great change from volcanic action, or the shifting and filling up of the ancient channels of rivers, are never discovered. The inference is plain, and we are irresistibly led to the conclusion, that long antecedent to the date of man, the surface of the earth teemed with life; and that it has been subject to mighty revolutions, which have, at once swept off its face, whole races of its former inhabitants, whose fossilized remains have formed the bed of a mighty ocean. It was therefore a splendid boast, that the deeds of the English chivalry at Agincourt made Henry's chronicle

——— as rich with praise
As is the ooze and bottom of the deep
With sunken wreck and sunless treasuries!

CHAPTER IV.

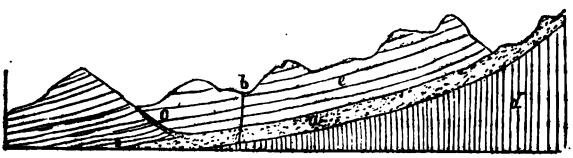
Springs.

"Thou dost wear
No stain of thy dark birthplace; gushing up
From the red mould and slimy roots of earth,
Thou flashest through the sun."

Bryant.

In the present chapter we shall consider another aqueous cause of change, springs, or as they have been termed "subterranean drainage." Every one is familiar with the fact, that the water which is deposited upon the loose soil, easily percolates through it, and makes its way downward to a certain depth according to the nature of the underlying strata. Whilst it easily penetrates through the gravelly, and sandy formations, it is arrested by the almost impervious beds of clay, and sometimes collected into large sheets of water, which are often subjected to intense pressure, upon the well known hydraulic principle so often employed in the arts under the form of the hydrostatic press. Mr. Lyell mentions that the transmission of water is so rapid through the loose gravelly soil over which the river Thames flows, and which is upon an impervious sub-stratum of clay, that the wells in this vicinity alternately ebb and flow, with the tides of the river. It is from this cause, that wherever on the side of a hill, strata of clay are found below sandy soils, the water oozes out, not indeed in a continuous sheet, but, probably from some slight difference in the constitution of the clay, or from natural fissures or cracks, in the form of little streams. The effect of such minute streams in finally undermining hilly tracts of country is surprising; constantly running, they bear out the light sand, and thus the subterraneous reservoir extends its surface gradually, until, at length, the superincumbent mass gives way, and sliding upon the slippery clay is precipitated into the valley below.

Much light has been thrown upon the theory of springs by the boring of what are called "Artesian Wells," so called from having been first made at Artois in France; they are made by boring the earth with a large augur, three or four inches in diameter. If a hard rock is met with, it is triturated with an iron rod, and the fragments are then easily removed; as the boring proceeds, tubes are introduced to prevent the sides from caving, and also the spreading of the water through the soil. In this manner a well was bored for Holt's Hotel, in the city of New York; 126 feet of stratified sands, clay, and river mud, were first penetrated before reaching the gneiss rock which underlies the island, 500 feet of this rock was subsequently bored through, and an abundant supply of good water obtained. When a vein of water is struck, it often rushes up with great force, rising several feet above the surface, affording a constant supply of water. Borings have been made in France to a depth of 1200 and even 1500 feet. Occasional failure is experienced in boring, sometimes on account of the geological structure of the country, and often from the existence of subterranean outlets for the water. The following diagram is from Mr. Lyell, and will illustrate the principle of the



Artesian wells. Suppose *a a*, to be a porous stratum lying upon an impervious bed of clays and marls, *d;* and covered by another mass of impenetrable rock *e*. Suppose now that at some point as at *b*, an opening be made which gives a free passage upward to the water confined at *a a*, at so low a level as to be subjected to the pressure of a considerable column of water, which we may suppose collected at *f*, in a more elevated district. The water will rush out at *b*, and rise to a considerable height; and if there should happen to be a natural fissure at *c*, a spring would be produced. Among the curious facts made known by the borer, is the existence of distinct sheets of water, in strata of different

ages and composition, and also of subterranean passages. At Tours, seeds and stems of marsh plants were brought up, and in such condition that they could not have been more than three or four months in water; and at Westphalia, small fish were thrown out, three or four inches long, the nearest streams being at the distance of some leagues. In boring an Artesian well near Buffalo, recently, for the purpose of obtaining pure water for the use of the Gas Works, after having penetrated some 25 feet from the surface, the laborers came upon limestone rock; upon penetrating this rock twenty-five inches, the drill fell into a cavity, and upon being withdrawn a jet of water followed, and continued to flow, until the water in the well rose to the level of the lake. Subsequent observations have shown Lake Erie to be the supply fountain, for when the waters of the lake rise or fall, by the action of wind, the water in the well changes its level in conformity. It appears that one of the large and numerous fissures common in this particular series of rocks, and which in this case communicated with the lake was pierced by the drill, and furnishes a fine illustration of the law which governs the production of springs and fountains.

By the long continued action of underground streams, caverns and fissures, are formed and enlarged, and it is highly probable that rivers are flowing within the surface of the earth. In Staffordshire there is a spring which discharges annually more water than all that falls in the surrounding country. In Virginia, ten miles from Harrisburg, is a spring called the "Big Spring." It rises suddenly from the foot of a limestone hill, and continues a stream some yards in breadth, and half a foot deep, with force sufficient to turn two large mills. At Kingston, Rhode Island, there is a spring which rises from primitive rocks, and discharges such a quantity of water that a grist-mill has been driven by it for a great number of years, and more recently a large cotton factory has been erected, which depends entirely upon the water of this spring to turn the whole machinery. In flowing through the different strata, springs become impregnated with various mineral substances. The solvent power of water exceeds that of any other liquid, and hence most spring waters are charged with

mineral substances; or with some gas. The presence of carbonate of lime, or lime in combination with carbonic acid, is easily shown by the calcareous lining or incrustation of a tea-kettle, or a boiler which has been sometime in use. Some springs contain so large a quantity of calcareous matter that they throw it down as they flow along, incrusting various objects which are placed in them. The springs of Derbyshire England, are particularly remarkable for this, and incrustations of leaves, branches, baskets &c., are easily procured. At the baths of San Fillippo, in Tuscany, where the waters are highly charged with carbonate and sulphate of lime; medallions are formed by first directing the water to a cistern where the sulphate of lime, (gypsum) is deposited. It is then conveyed to a chamber through a tube, from the end of which it falls ten or twelve feet, the current being broken by numerous small sticks crossing each other, by which means the spray is dispersed about the room. The moulds of the medallions are placed underneath, rubbed over with a little soap, and the water striking upon them leaves particles of carbonate of lime, which, gradually increasing, finally gives an exact and beautiful white crust. So rapid is the deposition of earthy matter by these springs, that a stratum of stone a foot thick is annually deposited, and is employed for building purposes. The hill of San Vignorn, in Tuscany, a few miles from San Fillippo, has a thermal spring upon its summit, and from this opening, a deposit of travertine, or concretionary limestone has been formed two hundred feet thick, and of great hardness. We must be careful and not confound these incrustations with true petrefactions. In the one case, as for example an incrusted twig, the inclosed sub-

stance will be found to have undergone no alteration, but that of natural decay, but a true petrefaction, is saturated throughout with

mineral matter, every part of its structure having undergone some change, so that if we break and polish such a specimen, every part of its structure, converted perhaps into flint, may be detected; even the minute ramifications and delicate tissues of many kinds of wood, and most delicate parts of the internal structure of bones. By the infiltration of water through limestone rocks, the sparry concretions are made which depend in caves, like icicles, they are called *stalactites*, from a Greek word meaning to drop, and also under them, from the drippings, are *stalagmites*, or drops, and when, as frequently happens, the two unite, a singularly picturesque effect is produced, the caves appearing as if supported by pillars of extraordinary beauty and variety. Sometimes a linear fissure in the roof, causes the formation of a translucent curtain or partition. This is the case in Weyer's cave, in the limestone range of the Blue Mountains, a narrow and rugged fissure leads to a large cavern where the most grotesque figures present themselves, formed by the infiltration of water through the limestone. Passing from these the passage conducts to a flight of steps that leads into a large cavern of irregular form and great beauty, about thirty by forty feet in dimensions. Here the incrustations hang like a sheet of water that has been frozen as it fell. Farther on is another vaulted chamber, one hundred feet long, thirty-six wide, and twenty-six high; still farther is another range of apartments, at the extremity of which, is a hall two hundred and fifty feet long, having a splendid sheet of rock work running up the centre. The whole length of this extraordinary group of caverns is not less than one thousand six hundred feet.

The most celebrated grotto in Europe, is in the island of Antipares, it consists of a series of caves, the roof, the floor, and the sides of which, are entirely covered with a dazzling incrustation. Immense columns of alabaster extend from the roof to the floor, and others hang in fine cubic forms above the head; the crystalization of alabaster has nowhere else been observed.

Although the phenomena produced by incrusting springs, are perhaps not of much importance in modifying or changing the surface of the earth, yet the changes effected by this process, in

strata composed of loose materials are of very great importance; for by an infiltration of carbonate of lime, sand is converted into sandstone, and soft chalk into solid rock, and the loose shells of Florida into compact stone. By this agency, the beds of recent limestone in which human skeletons are sometimes found, have been formed, and are now in progress of formation, along the shores of the whole West Indian Archipelago. On the north-

east corner of the main land of Guadalope is a bed of recent limestone, nearly submerged at high tides. In it are found shells, fragments of pottery, stone arrow-heads, wooden and stone ornaments, and human skeletons. It is quite evident that the rock must have been soft and yielding when these remains were first deposited, they are not fossilized, for the bones still retain their gluten and phosphate of lime. In the wood cut, we give a representation of one of these human skeletons which is now in the British Museum, it is that of a female; the head of this skeleton has been carefully examined by Dr. Moultrie, and is now in the museum of the Medical College at Charleston, South Carolina.

This skeleton appears, from the craniological developments, to have belonged to a Peruvian, or to some one of a similar race, being entirely dissimilar to the skulls of the Caribs, or ancient possessors of the island. Another skeleton in a sitting posture is in the museum at Paris. The formation of this limestone is as follows. The sea which surrounds the Bermudas, abounds in corals, and shells, and from the incessant action of the waves, the water becomes charged with calcareous matter, and a portion of this is borne by the waves to the shore, and deposited in the form of calcareous sand, which becomes compact limestone, on the infiltration of crystalized carbonate of lime. A great part of the detritus is thrown down in the depth of the ocean, and there envelopes the remains of vegetables and animals, forming new strata for the investigation of future ages.

Carbonate of lime is not the only mineral substance held in solution by water, but silicious earth, or the basis of flint, which constitutes so large a proportion of the surface of the earth, is found in great abundance in some springs. It is true, that even in the present advanced state of chemical knowledge, we are unacquainted with any process by which any large proportion of flint can be held in solution by water. Yet we have unquestionable proofs that in the great laboratory of nature, this is effected on a large scale, as for example in the Geysers of Iceland, and the springs of Carlsbad in Bohemia, and the thermal springs of St. Michæl, in the Azores. It seems necessary in order that water should contain any large quantity of silica in solution, that it should be raised to a high temperature, and silicious springs are mostly thermal, and are generally found in volcanic regions. The most celebrated thermal springs are those of Iceland, termed the Geysers. The waters of these boiling springs contain a large amount of silex which is deposited on cooling, upon various substances, similar to the incrustations of carbonate of lime already noticed. The hot springs of Iceland are situated in the southwest section of the island, and more than a hundred of them are found in a circuit of two miles. They rise through a thick current of lava, which may have flowed from Mt. Hecla, whose summit may be seen at a distance of about thirty miles. It is said

that the rushing of the waters may be heard as they flow in their subterranean channels. The springs are intermittent, a fountain of boiling water accompanied with a great evolution of vapor, first appears, and is ejected to a considerable height, sometimes as much as one hundred feet, a volume of steam succeeds, and is thrown up with great force and a loud noise, similar to the escape of steam from the boiler of an engine. This operation continues sometimes for more than an hour, though generally not longer than ten minutes, and is succeeded by a period of rest of uncertain duration, and then a repetition of the same phenomena. We give a view of the crater of the great Geyser reduced by Mr. Lyell, from a sketch by J. W. Hooker, M. D. The basin of the great Geyser is an irregular oval about fifty-six feet, by forty-six, the silicious mound of which it is formed, is about seven feet high. In the centre is a pipe seventy-eight feet in perpendicular depth, and about sixteen feet diameter at the top, but contracting to ten feet lower down. The circular basin is represented as

empty, but it is usually filled with a beautifully transparent water in a state of ebullition; the inside of the basin is smooth and formed of a whitish silicious deposit, as are also two channels at

each side, by which the water escapes when the basin is full. It is said that an eruption may be brought on in a few minutes by throwing stones down the pipe, these are again ejected, oftentimes with immense violence. The theory of the action of these hot springs of Iceland has not yet been satisfactorily given; the heat however, is supposed to be derived from subterranean volcanic fires. The silicious water from these springs incrusts plants, twigs, and leaves, similar to the calcareous springs. In the island of St. Michael there are hot springs very strongly impregnated with silica; wherever the water has flowed, sinter or precipitated rock, is formed intermixed with the clay, including grass, ferns, and reeds, in different stages of petrefaction; branches of the same ferns which now flourish in the island are found completely petrified, preserving the same appearance as when vegetating. There are many springs in this country which deposit silicious and calcareous matter.

Iron is found in the waters of almost all springs, and some of them are so copiously impregnated with this metal that they stain the rocks or herbage over which they flow. The iron which is thus borne out of the earth and deposited into the sea, acts as a cement to bind together the subaqueous deposits now forming.

Many of the ancient sandstones are cemented and colored by iron, and pebbles are firmly bound together in ferruginous con-

glomerate. Occasionally nails, or other pieces of iron, are found in the centre of a hard nodule of sandstone, formed by this process. The engraving, from Dr. Mantell's "Wonders of Geology," is a very interesting specimen, it is a conglomerate of glass beads, knives, and sand, cemented together by an infiltration of iron, derived from the oxidation of the blades. It contains two silver pennies of Edward I, and was dug up at a depth of ten feet in the river Dove in Derbyshire. The coins are presumed to have been a part of the treasures contained in the military chest of the Earl of Lancaster, which was lost in crossing the river in the dark; more than five centuries must therefore have elapsed since its submersion. The ore called bog-iron, is formed by the infiltration of water impregnated with iron, and various kinds of wood are colored black by the same cause. Iron, it is well known is one of the chief ingredients in many celebrated mineral waters, frequently in the shape of a carbonate. The consolidation of sand and other loose materials by the agency of mineral waters, is everywhere going on, and in much greater extent than can be easily comprehended; small and apparently simple as are the means employed, yet the effects are magnificent.

The detritus borne down by the mountain streams falls at last, quietly into the ocean, or is deposited upon the rich soil of some delta, after a certain time the mass is cemented together by other mineral ingredients dissolved in the water, and beds of compact stone, in which are entombed the remains of animate and inanimate existence, are formed slowly but surely, for the use of most distant generations. The twigs and leaves, and insects, which fall into the petrifying springs are incrusted with a coating of stone, or are slowly transmuted into mineral substance for the inspection and admiration of a future race. Thus the change continually goes on. The frost, the storm, and the stream, and in many volcanic districts the carbonic acid, continually given off, as for example, in the neighborhood of the extinct volcanoes of Auvergne in France, cause even the granite rocks to crumble and fall away; but in a thousand other places the process of reunion is going on, and different kinds of stone are being formed from the ruins of the old. Besides the springs to which we have

referred, there are others very numerous impregnated with petroleum, and the minerals allied to it, as bitumen, naptha, asphaltum and pitch. These springs are found in all parts of the globe, but the most powerful yet known, are those on the river Irawadi, in the Birman Empire, there being five hundred and twenty wells in one locality, yielding annually 400,000 hogsheads of petroleum. On both sides of the island of Trinidad, fluid bitumen is seen to ooze up from the sea. In the island is a pitch lake about three miles in circumference. The asphaltum is sufficiently hard to support heavy weights in cold and wet weather, but during warm weather it is nearly fluid. In some places it is covered by the soil, and large crops of tropical productions are raised upon it, so that it is difficult to ascertain the boundaries of the lake. Mr. Lyell supposes that the materials for the formation of this bitumen, have been borne down by the Oronoco into the sea; and, collected by eddies or other causes into particular regions, have been acted upon by submarine volcanic fires. The frequent occurrence of earthquakes, and other volcanic phenomena in the island, lends countenance to this opinion.

In addition to those above mentioned, we may enumerate the saliferous or brine springs, which are everywhere so common over the globe. The agency of these springs, in the formation of rocks, is of less importance than that of the calcareous, or the silicious. Often they are strong solutions of pure rock salt, or *muriate of soda*, and furnish large quantities of that valuable article for the purposes of domestic economy. Such are the salt springs in the neighborhood of Salina, and Syracuse, in the State of New York. At Salina, the well is seventy feet deep, and about 480 gallons of brine are raised in one minute, and Dr. Beck states that 43½ gallons are required to yield a bushel of salt, weighing 56 lbs. The well at Syracuse 170 feet deep, the pumps raise 62 gallons per minute, and 46 gallons are required to make a bushel of salt. The water is clear and sparkling, and of a temperature of 50° (Fahr.) at Salina, and 51° at Syracuse. These salt springs are supposed to be owing to immense beds of rock salt, although no borings yet made, have reached these beds. The valleys of the Mississippi and the Ohio abound in salt springs,

and are based almost wholly on the saliferous or salt bearing rocks. Two distinct strata of these salt rocks, known as the upper and lower salt rocks, are found on the Muskingum, about 400 feet apart. The stone itself is a white, or sometimes reddish tinted and porous sandstone, the upper, is 25 feet thick; and the lower 40, and this yields the strongest brine. At Cheshire England, are numerous brine springs, and the salt springs of Droitwich, a small town in Worcestershire, are superior to any other in the island; they are supplied from beds of rock salt, or rather veins, lying below a bed of gypsum; for a long time the salt was made only from the brine which penetrated this bed, but about a century ago it was bored through and a large salt river was found to flow below. The depth of the river of brine below the surface, is about 200 feet, 150 of which are gypsum; the river flows over a bed of rock salt and is twenty-two inches deep. The origin of these extended deposits of salt has not yet been satisfactorily ascertained. The waters of the Dead Sea in Palestine, contain large quantities of muriatic salts, derived from entire rocks of this mineral, continually dissolving on its southern shore. The water contains forty-one parts in one-hundred of salt; a much greater proportion than that of the sea. It is impregnated also with other mineral substances, particularly bitumen, which floats upon its surface in such large quantities as would elsewhere sink. The volcanic appearance of the country, the almost perpendicular, black rock which bounds its eastern or Arabian side, and throws its black shadow over the dark waters, and the limestone and sandy cliffs on its western side, which tower up in fanciful shapes, lends countenance to the opinion that these mineral substances are the products of former volcanic action. We have now glanced at the most prominent effects of springs in modifying and changing the face of the globe; although the effect of any individual spring appears trifling, yet the aggregate of change either by disintegrating, or consolidating, is immense. We have already alluded to the transporting power of rivers. The small stream which is supplied by springs, and which flows for hundreds of miles with a power which seems scarcely sufficient to carry along a few sands, by continual accessions swells finally into an immense

river, and when, from long continued rains, or from melting of snows and ice, the brooks and tributary streams are swollen, a flood of water is poured down to the ocean, which bears with it materials transported a thousand miles, and in quantities of which we can form little conception. The water, which falls upon the surface of the earth and penetrates its upper soil, and is thus protected from evaporation, descends lower and lower, until it meets some impervious bed of clay, or marl; here it accumulates and forms a hidden pond, and slowly undermines whole tracts of country, and in the course of ages subterranean rivers are formed. The various mineral ingredients dissolved in water, are borne up by springs, and again flowing over or through the porous sands, form limestones, sandstones, and ironstones; and thus continually the process is going on.

The action of all springs, and running waters, is to level the surface of the earth. The streams, which always flow from an elevated source, bear down the disintegrated portions of mountains and hills, and tend continually to fill up the bed of the sea. Unless a counterbalancing cause existed, and the elevation was made to compensate this continual degradation or levelling, the whole dry land would ultimately disappear. We find in earthquakes and other volcanic effects the elevating power; and although, as we shall presently show, the sea may gradually encroach upon the shores of one country, yet the lands of another will be gradually upheaved, and something like a balance will be maintained. Minute therefore as are the transmutations which are going on continually around us, and by which, long since, in the same quiet manner, the leaf that floated down the stream, a thousand years ago, and the insect that dropped into water, have been incrusted, and preserved with a fidelity which mocks the sculptor's art, yet we see that processes like these, have

> "Turned the ocean-bed to rock,
> And changed its myriad living swarms
> To the marble's veined forms."

"How marvellous" observes Sir Humphry Davy, "are those laws by which even the humblest types of organic existence are

preserved, though born amidst the sources of their destruction; and by which a species of immortality is given to generations, floating, as it were, like evanescent bubbles on a stream raised from the deepest caverns of the earth, and instantly losing what may be called its spirit in the atmosphere."

CHAPTER V.

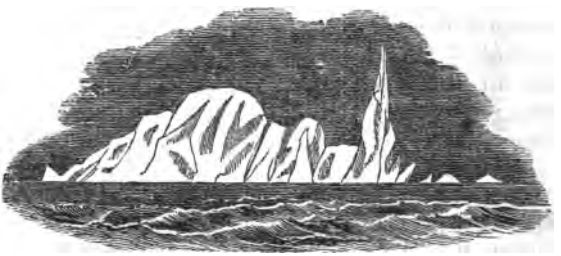
Currents.

"Thy shores are empires, changed in all save thee —
Assyria, Greece, Rome, Carthage, what are they?
Thy waters wasted them while they were free,
And many a tyrant since; their shores obey
The stranger, slave, or savage; their decay
Has dried up realms to deserts: — not so thou,
Unchangeable, save to thy wild wave's play —
Time writes no wrinkle on thine azure brow —
Such as Creation's dawn beheld, thou rollest now!"

Byron.

We are now to consider the remaining aqueous causes of change, currents and tides. The joint action of these produce mutations of great geological interest. The tides, or the great tidal waves which flow over the surface of the ocean at stated intervals, are mainly caused by the attraction of the moon, and hence we may show, and by no very extended chain of causation, that the effect of the moon in altering and keeping in a state of perpetual mutation the face of the earth, is by no means inconsiderable. A more remote cause, the rotation of the earth upon its axis, produces in part at least, great currents which constantly flow in vast circuits in the Atlantic, Pacific, and Indian oceans. In addition to the circular currents which thus flow through the oceans which we have named, there are immense bodies of cold water continually moving from the polar regions towards the central portions of the earth, and, as these currents are exhibited superficially, or on the surface, bearing down immense fields of ice, and since the storms and fogs of those regions are not sufficient to supply this waste of the waters, we may infer that an under current of warmer water passes continually from the equatorial to the polar regions. The polar current of the southern regions seems to be more powerful than that of the northern. Ice

islands from 250 to 300 feet above the level of the sea, have been occasionally seen off the Cape of Good Hope, and were therefore of immense bulk, as for every solid foot seen above, there must have been at least eight cubic feet below water. The wood cut below exhibits one of these ice-islands, sketched by Capt. Horsburgh; it was seen off the Cape of Good Hope, in April 1829; it was two miles in circumference and about 150 feet high, appearing like chalk when the sun was obscured, and having the lustre of refined sugar when the sun was shining upon it.



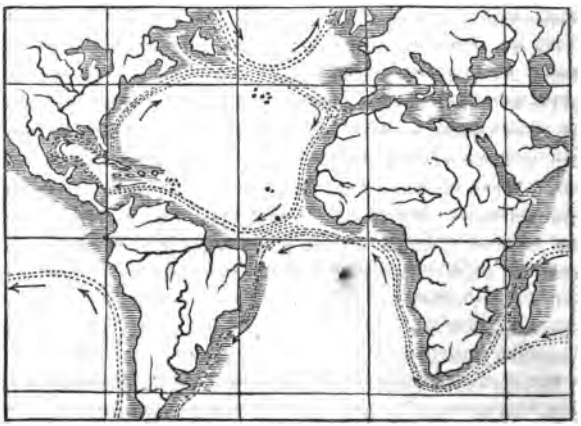
Undoubtedly the principal causes of Oceanic currents are the trade-winds, of which we have already spoken. These blowing at first directly from the north and south, over the surface of the water, move the floating ice, and superficial water, in the same general direction, thus at length generating a strong polar current. The south polar current being less intercepted by the peculiar formation of the antarctic lands, than the northern, is perceptible in much higher southern latitudes than the current from the north. A manifest influence is thus exerted upon the climate, to which we shall again allude.

The rotation of the earth, when the waters have been set in motion from the north to the south, causes a great change in the general direction of these currents precisely upon the same principle which has long been recognized in the case of trade winds. For example, the current which flows north from the Cape of Good Hope towards the Gulf of Guinea, has a rotary velocity when it doubles the Cape of about 800 miles per hour, but when it reaches the equator, the surface of the earth is there whirled around at

the rate of 1000 miles an hour, or 200 miles faster. Now if the water was to be suddenly transferred from the Cape to the equator, this deficiency of motion would cause, (inasmuch as the earth rotates from west to east) a very strong current flowing westward at the rate of 200 miles an hour; or with sufficient power to submerge the western continent. No disturbance however occurs, for the water, as it advances into new zones of sea which are moving more rapidly, gradually acquires the different velocity by friction, so that a gentle easterly, or south-easterly current is the result. When the water flows from equatorial to polar regions, a contrary current is produced; thus the Gulf Stream, issues from the Bahama Channel with a rotary velocity of 940 miles an hour, but when it reaches latitude 40°, the water is there moving with a rotary velocity of 766 miles an hour, or 174 miles an hour slower, hence a westerly or south-westerly current is the result from the excess of rotary motion retained by the stream.

Having shown some of the causes that produce oceanic currents, we will now consider more in detail the most important. From the best accounts which we have been able to obtain, there seems to be a general set of the waters westward from the western coast of Peru. This current flows nearly westward, but is not much perceived until its entrance into the Indian Ocean, when, strengthened by the northerly currents flowing from the North Pacific, it flows along the east coast of of Africa; after passing through the Mozambique Channel, between Madagascar and the continent, it unites with another current from the Indian Ocean, and is deflected by the Lagullas banks, which lie off the southern point of Africa, around the Cape of Good Hope. The collective stream is about one hundred and thirty miles in breadth and from 7° to 8° warmer than the neighboring water, and runs from the rate of two and a half to more than four miles an hour. The Lagullas bank rises from an immense depth to within one hundred fathoms of the surface, and has perhaps been formed by the joint action of a south-eastern and north-eastern current, which meet here. As the main body of the current does not flow over this bank we may conclude its total depth to be much more than one hundred fathoms. We give here a little chart showing the

general direction of the great oceanic currents. The Lagullas current after doubling the Cape of Good Hope, passes northward



along the western shores of Africa, and is called the South Atlantic current. It then enters the Bight, or Bay of Benin, and is deflected westward, partly from the form of the coast and partly by the action of the Guinea current flowing from the north into the same great bay. From the centre of this bay it proceeds in an equatorial direction westerly, at the rate of ten or eleven miles a day, to the coast of Brazil where it is divided, a portion flowing feebly southward; the other branch passes off the the shores of Guinea by the West India islands, towards the Musqueto and Honduras coasts, through the Carribean sea, flowing northwards, passes into the Gulf of Mexico, following the bendings of the shore from Vera Cruz to the mouth of the Rio del Norte, thence to the mouths of the Mississippi where it receives a new impulse; after performing this circuit, it rushes with great impetuosity through the Bahama Channel, its velocity being about five miles an hour, and breadth from thirty-five to fifty miles. Its course is now north-easterly along the eastern coast of North America, its breadth increasing and its velocity diminishing. As the cur-

rent moves along northward, it retains a large proportion of the warmth which it had in the Gulf, and is easily recognized from the rest of the ocean by its higher temperature, even as far north as the banks of Newfoundland, where the temperature is from 8° to 10° above the surrounding ocean. To the east of Boston and in the meridian of Halifax, the stream is two hundred and seventy-six miles broad. Here it is suddenly turned to the east, its western margin touching the extremity of the great bank of Newfoundland, where the current sends off a branch which proceeds to the north-east, sometimes depositing tropical fruits and seeds upon the coast of Norway, and the shores of Ireland and the Hebrides. The main current continues to flow and spread out until, in the neighborhood of the Azores, it is about five hundred miles in breadth. From the Azores it flows towards the straits of Gibraltar, the island of Madeira, and the Canary isles, along the western shores of Africa as far south as Cape Verd, where it is again deflected by meeting the great equatorial current flowing from the coast of Guinea to the Brazils. In this manner, according to Humboldt, the waters of the Atlantic are carried around in a continual whirlpool, performing a circuit of 13,000 miles in about two years and ten months. The branch of the Gulf Stream which is given off near the banks of Newfoundland, passes northward and eastward by the coast of Scotland and Norway, as far as the North Cape, where, being met by a polar current from Nova Zembla, it is deflected westward along both sides of Spitzbergen; still influenced by the polar current, it passes along the shores of Greenland to Davis' Straits, where it meets a fourth current from Baffins Bay, which deflects it southward towards the banks of Newfoundland, where it again meets the Gulf Stream. Thus two great whirlpools, connected with each other and revolving in opposite directions, touch at the Banks of Newfoundland, which seems to be a bar cast up by their conflicting waters. Branches of the Gulf Stream sent off at the Azores, set from the Bay of Biscay through the English Channel, and through St. George's Channel. The general direction of these great currents may be observed on the little chart preceding. Besides these great currents, there are local or tem-

porary currents, produced by winds, the discharge of rivers, the melting of ice, &c.

The great oceanic currents however depend upon no temporary or accidental circumstances, but like the tides, on the laws which regulate the motions of the heavenly bodies. The lines of coast which are subjected to their continual action, are undergoing perpetual change, the amount of this change being dependant upon the exposure, and the actual constitution of the coast. We find everywhere, the most lofty cliffs, promontories, and precipices, whatever be their composition, whether like the primary deposits of the Shetland isles, or like the chalk cliffs of Dover, or the diluvium of Boston Harbor, all in a state of rapid and fearful destruction, crumbling away more or less quickly according to the hardness and crystalline character of the materials which compose them. The whole of Boston Harbor, which is now dotted with small islands, was once one piece of solid land. The diluvium which formerly covered the rocks, has been gradually worn away by the ocean, the outermost islands present nothing but the bare rock, and the inner ones are now being denuded. Indeed, as Prof. Hitchcock observes, when writing of the effect of the ocean upon coasts exposed to its fury, "It is difficult to examine the coast of Nova Scotia and New England, to witness the great amount of naked battered rocks, and to see harbors and indentations, chiefly where the rocks are rather soft, while the capes and islands are chiefly of the hardest varieties, without being convinced that most of the harbors and bays, have been produced by this agency." To witness in perfection the immense power of the waves, urged by the tempests and currents upon the coasts exposed to their irresistable force, we must visit the northern isles of Scotland, and behold steep cliffs hollowed out into deep caves and lofty arches; and immense blocks of stone overturned and carried incredible distances. In the winter of 1802, in the isle of Stenness, says Dr. Hibbert, a tabular shaped mass of rock, eight feet two inches, by seven feet, and five feet one inch thick, was dislodged from its bed and removed to a distance of from eighty to ninety feet; and on Meikle Roe, one of the Shetland isles, a mass of rock twelve feet square, and five

feet in thickness, was removed from its bed fifty years ago, to a distance of thirty feet, and has since been twice turned over.

The long continued and violent action of the surf, finally frets away the softer parts of islands, and nothing remains but fanciful clusters of rocks, and mere shreds and patches of masses once continents. We give below a view of the cluster of rocks to the south of Hillswick Ness, one of the Hebrides, from a sketch by

Dr. Hibbert. These fantastic shaped rocks, which are all that remain of what was once an island covered with vegetation, are striking monuments of that incessant change which, continually, though silently and almost unnoticed, is going on, but whose final effects are of the most magnificent character. Examples of such rocks as are figured above, are found in many places along the coast of the United States, where it is exposed to the action of the storms of the Atlantic. We may be able to form some idea of the degrading power of the ocean from the following statement, which is given on the authority of Lieut. Mather, geologist to the first district of the state of New York.

"Vast masses of the cliffs of loam, sand, gravel, and loose rocks, of which Long Island is composed, are undermined and washed away by every storm. The water on the ocean coast, to some distance from the shore, is almost always found to have

more or less earthy matter in suspension, much of which, except during storms, is derived from the grinding up of the pebbles, gravel, and sand, by the action of the surf. This earthy matter is carried off during the flood tide, and in part deposited in the marshes and bays, and the remainder is transported seaward during the ebb, and deposited in still water. After a close observation, I have estimated that at least 1000 tons of matter is thus transported daily from the coast of Long Island, and probably that quantity, on an average, is daily removed from the south coast, between Montauk Point and Nepeaque Beach. This shore of 15 miles in length, probably averages 60 feet in height, and is rapidly washing away; 1000 tons of this earth would be equal to about one square rod of ground, with a depth of 60 feet. Allowing this estimate to be within proper limits, more than two acres would be removed annually from this portion of the coast. It is probable that any attentive observer would not estimate the loss of land there at less than this amount. Nearly one half the matter coming from the degradation of the land is supposed to be swept coastwise in a westerly direction. There are many evidences that the east end of Long Island was once much larger than at present; and it is thought probable that it might have been connected with Block Island, which lies in the direction of the prolongation of Long Island."

A remarkable exhibition of the conjoint power of waves and currents was exhibited during the building of the Bell Rock Lighthouse. The Bell Rock, on which it stands, is red sandstone, about twelve miles from the mainland, and from twelve to sixteen feet under the surface at high water. At a distance of 100 yards from the rock, there is a depth in all directions, of two or three fathoms at low water. During the erection of the lighthouse in 1807, six large blocks of granite, which had been landed on the reef, were carried away by the force of the sea, and thrown over a rising ledge to the distance of twelve or fifteen paces, and an anchor weighing 22 cwt. was thrown up upon the rock. We are informed by Mr. Stevenson, that drift stones of more than two tons weight, have, during storms been often thrown upon this rock from the deep water.

The eastern coast of England has been greatly changed by the action of the waves, the ancient sites of towns and villages, being now sand banks in the sea. The whole coast of Yorkshire, from the mouth of the Tees to that of the Humber, is in a state of comparatively rapid decay; the inroads of the sea at different points being limited by the nature of the soil, or the hardness of the rocks. Pennant, after speaking of the silting up, or filling up with water transported sand, clay, gravel, &c., of some ancient posts in the estuary of the Humber, observes, "But in return, the sea has made most ample reprisals, the site, and even the very names of several places, once towns of note on the Humber, are now only recorded in history; Ravensper was at one time a rival to Hull, and a post so very considerable in 1332, that Edward Baliol, and the confederated English barons, sailed from hence to invade Scotland; and Henry IV. in 1399, made choice of this port to land at, to effect the deposal of Richard II; yet the whole of this has long since been devoured by the merciless ocean; extensive sands, dry at low water, are to be seen in its stead." Instances like these are not rare, the towns of Cromer, and Dunwich, are both lost, swallowed up by the ocean, which is now encroaching at Owthone at the rate of about *four yards a year*. At Sherringham, in Norfolkshire, where the present inn was built in 1805, and the sea was a distance of fifty yards, the mean loss of land being about one yard annually, it was calculated that it would require about seventy years before the sea would reach that spot, but between the years 1824 and 1829 no less than seventeen yards were swept away, and a small garden only, was left between the house and the sea, and when Mr. Lyell in 1829 visited the place, he found a depth of twenty feet, (sufficient to float a frigate), where, only forty-eight years ago, stood a cliff fifty feet high. Mr. Lyell justly remarks, "If once in half a century an equal amount of change were produced suddenly, by the momentary shock of an earthquake, history would be filled with records of such wonderful revolutions of the earth's surface; but if the conversion of high land into deep sea be gradual it excites only local attention." The flag-staff of the Preventive Service station, on the south side of the harbor, has, within

the last fifteen years, been thrice removed inland, in consequence of the advance of the sea.

Along the whole eastern coast of England, changes similar to these are going on. In some places by the silting up of estuaries, land is forming, but not near as much, as is being removed. The isle of Sheppey, which is a tertiary formation, now about six miles long, by four in breadth, is rapidly decaying on its north side, fifty acres of land having been lost within the last twenty years. To the east of Sheppey stands the Church of Reculver, upon a cliff of clay and sand, about twenty-five feet high. This place was formerly an important military station in the time of the Romans, and even so late as the reign of Henry VIII, was nearly one mile distant from the sea.

We here give a view of the Church of Reculver taken in the year 1781, copied from the Gentleman's Magazine. At this time the spot had become interesting from the encroachment of the water. It represents considerable space as intervening between the churchyard and the cliff. In the year 1782, the cottage at the right was demolished; nearer the church is shown an ancient chapel now destroyed, and at the extreme right is the Isle of Sheppey. In the year 1806, a part of the Churchyard with some

of the adjoining houses was washed away, and the ancient church with its two lofty spires, a well known land-mark, was abandoned. The following view of it as it appeared in 1834, is taken from Mr. Lyell's Principles of Geology, from which the preceding statement is also derived. This ancient building would

probably, have fallen long since, had not the force of the waters been checked by an artificial causeway of stones, and large wooden piles, driven into the sands to break the force of the waves.

There are good reasons for believing that the coasts of France and England were formerly united, this is inferred from the identity of the composition of the cliffs on the opposite sides of the channel, and also of the noxious animals in England and France, which could hardly have been introduced by man. This opinion is advocated by many distinguished geologists, and it is by no means incredible, that in the course of ages the sea may have forced its passage through. The separation of Friesland, which was once a part of North Holland, from the mainland, by the action of the

sea in the thirteenth century, and the formation of a strait of about half the width of the English channel in 100 years, lends countenance to this opinion. The inroads of the sea have no where been more severe than in Holland, and even at the present day 12,000 windmills are employed to drain the Netherlands and to prevent at least two-thirds of the kingdom from returning to the state of bog and morass, and during the past year three immense steam engines, capable of discharging 2,800,000 tons of water in 24 hours, have been employed in pumping out and emptying through the great ship canal, and sea-sluices at Katwyk, the lake of Haarlem, which by its continual inroads threatened to inundate Amsterdam on the one side, and Leyden on the other. In the year 1836, twenty-nine thousand acres of land were completely overflowed by it. The large lake called the Bies Bach was formed in 1621, by the sea bursting through the embankments of the river Meuse, overflowing seventy-two villages. Of these villages no vestiges of thirty-five of them were ever discovered. Since their destruction an alluvial deposit has been formed partly over their site. The island of Northstrand, which in the year 1634, contained 9000 inhabitants, and was celebrated for its high state of cultivation, was, on the evening of the 11th of October, in that year, swept away by a flood which destroyed 1300 houses, 50,000 head of cattle, and 6000 men, leaving three small islets, one of them still called Northstrand, which are continually being wasted away by the sea. Such are some of the powerful effects of currents and waves in altering, and finally sweeping away the headlands and islands which at any particular epoch may have distinguished the line of coast exposed to their force; the eastern side of America, along the Atlantic coast is subject to the same changes. Before leaving this part of our subject, we will describe that peculiar tidal wave called "the Bore." This is produced, when the channel of a river, into which the tidal wave from the ocean is entering, is so narrow that the water is made to rise suddenly, and thus terminates abruptly on the side away from the sea, or inland; precisely like the waves which break upon a shelving shore. As might be expected, this phenomenon occurs most powerfully at the time of spring, or high-

est tides. The Bore which enters the river Severn is sometimes nine feet high, and at spring tides rushes up the estuary with extraordinary rapidity. In the Hoogly or Calcutta river, says Rennell, "the Bore commences at Hoogly point, the place where the river first contracts itself, and is perceptible above Hoogly town; and so quick is its motion, that it hardly employs four hours in traveling from one to the other, though the distance is nearly seventy miles. The tides of the Bay of Fundy pour twice a day vast bodies of water through a narrow strait, causing in every small stream, an immense tidal wave, rising sometimes to the height of seventy feet. We have already alluded to its rich alluvial deposits of red marl which have been excluded artificially from the sea by embankments.

Heretofore we have noticed only the degrading effects of currents, and tides. It might at first appear that the sediment borne down by rivers, the formation of deltas, and the silting up of estuaries, would compensate for the loss by the encroachments of the sea, this however, is not the case; while in all instances the new-made land is constantly attracting attention, there are no boundaries, or great natural land marks, to show where was formerly the line of coast. The former demand attention by their presence, the latter are unseen, and therefore lightly estimated; many places where once flourishing cities stood, are now, not only depopulated, but covered with water to a depth of thirty feet. There is therefore good reason for believing that the loss of land by the effects of currents and tides, much more than counterbalances all deposited in the form of dry land.

The general tendency of these encroachments is undoubtedly to fill up the bed of the sea, and to finally reduce the surface of the earth to a uniform level; and this would ultimately be accomplished, but for the counterbalancing force of volcanic or igneous causes, which are continually elevating the surface. If we had space we might continue to enumerate examples of the effects of the ocean in destroying the coasts, not only of our own country, but over the whole world: sufficient however has been said to give some idea of the importance of these causes of change, and when hereafter, we allude to immense formations of rock

strata, imbedding numerous fossils, as the sedimentary deposit of an ancient ocean, the statement will not appear incredible. The force of the current of the Amazon extends out into the ocean to a distance of three hundred miles from its mouth, and when we remember how long the mud and fine sand remains suspended even in quiet water, we shall not be surprised to learn that particles brought down from the interior of South America, are perhaps deposited in the Mexican Gulf; for where the great equatorial current from the coast of Guinea crosses the waters of the Amazon, it runs with a velocity of four miles an hour. Vast quantities of drift wood and rubbish are thus carried as far as the mouths of the Orinoco, and are increasing the island of Trinidad. It is the opinion of many distinguished philosophers that the Isthmus of Suez, which now separates the Mediterranean and the Red Sea, is a recent formation, it is at least quite certain that the isthmus is receiving continual accessions on the Mediterranean side. The change of coast, the loss of cities, the formation of bays, the filling up of estuaries and washing away of islands, important as these changes may be, are nevertheless, of less moment than the processes going on in the depths of the sea; far below, where the waters are never disturbed by the storms and winds, which lash the surface into fury, a quiet deposit is going on, in this are now being imbedded the various forms of animal existence which are borne down to the bottom of the ocean. Nor are these all, the wealth of man has gone down, and lies burried deep with his bones in the undisturbed strata. At some distant epoch, when the present ocean bed shall be upheaved, perhaps some patient investigator will exhume the fossils, and moralize upon the eventful change which passeth over all things. We cannot close this chapter better than with the beautiful language of Mrs. Hemans:

"The depths have more! What wealth untold
Far down and shining through their stillness lies!
They have the starry gems, the burning gold,
Won from a thousand royal argosies!

Yet more — the depths have more! Their waves have roll'd
Above the cities of a world gone by —
Sand hath filled up the palaces of old,
Sea-weed o'ergrown the halls of revelry."

CHAPTER V.

Volcanic Eruptions.

"Yon dreary plain, forlorn and wild,
The seat of desolation, void of light,
Save what the glimmering of these flames
Casts pale and dreadful." *Milton.*

We have in the preceding chapters given somewhat in detail an account of the various aqueous causes of change, now in operation. We shall consider in the present chapter the igneous causes of change, or volcanic action; and in order to economise the little space we can allow, will consider them as follows. First, we shall give a sketch of the geographical distribution of the chief volcanoes now active, or which have been active within the historic era. We shall next give an account of the principal earthquakes, and other volanic phenomena which have disturbed the earth's surface; and lastly, consider such changes, supposed to be due to internal igneous agency, as the gradual elevation and depression of various tracts of country. It would be out of place for us to discuss at present, the question, whether the interior of the globe is in a state of fusion, and that the eruptive force of volcanoes is the occasional liberation of the molten mass, acted upon by the intense pressure of the superincumbent strata, or by confined gases and vapors; or whether the intense heat which melts masses of rock, causing the most violent convulsions, is caused by chemical action, i. e. the union of oxygen derived from water or the air, with the metallic bases of the earths and alkalies, forming silica, alumina, lime, soda, &c., substances which predominate in lavas; or whether it be a union of both these causes. In our own opinion it is neither, but is the result

of simple mechanical action, produced in a manner we cannot here describe.

Volcanoes are found distributed all over the surface of the earth, though more prevalent in some portions than in others. Many of the islands in the Pacific and Atlantic are of volcanic origin; perhaps the majority of them. In some parts of the earth volcanoes stand alone, but they are mostly connected with extensive mountain ranges, extending in a linear direction, and we may select three distinct regions of subterranean disturbance. The most extensive is that of the Andes. Along the whole western shores of North and South America, extends a lofty mountain chain, remarkable not only for its position, but also for its collosal form, the nature of the masses of which it is composed, and of the materials ejected. Along the whole extent of this chain, volcanoes occur, and between the 46th deg. of south latitude to the 27th deg. is a line of volcanoes so uninterrupted that scarcely a degree is passed without the occurrence of one of these in an active state; about twenty now active are enumerated in this space, and doubtless there are very many more which have been active at a recent period. When we remember how long a time Vesuvius had remained quiet, before it again renewed its activity, and overwhelmed the cities of Herculaneum and Pompeii, we can readily admit that the number of volcanic vents or craters is much greater than really is now apparent. The immense height of the volcanic mountains of the Andes and Cordilleras is very remarkable, and the craters are all formed by bursting through porphyritic rock, or igneous unstratified rock, containing crystals of feldspar. Some of the loftiest summits are composed of trachyte, a rock of igneous origin, unstratified and allied to the trap rocks, such as basalt, greenstone, &c. On the summits are found large quantities of obsidian, or dark green volcanic glass, pumice stone, and tuff formed out of cinders, and fragments of lava cemented together.

It appears highly probable that a chain of volcanic vents extends quite around the globe, in the general direction north and south. A lofty chain of mountains was discovered by Capt. J. C. Ross, in the Antarctic regions in year 1841, at a distance of

about 800 miles from the south pole. Two of the loftiest of these were named from his vessels, Mount Erebus, and Mount Terror, they are each about 12,000 feet in height, and the former is an active volcano. This range of mountains is probably connected by a submarine chain with the Andes, first appearing in Terra-del-Fuego, near which Capt. Basil Hall is said to have witnessed volcanic eruptions. As we proceed north along the western shore of South America, we find in Chili, a large number of active volcanoes, and, what we might reasonably expect, the country continually disturbed by earthquakes, and abounding in hot springs. Villarica is the principal of the Chilian volcanoes, it burns without intermission, and is so high that it may be seen at a distance of 150 miles. It is said that a year never passes in this province, without some slight shocks of earthquakes, and sometimes the most tremendous convulsions occur. As we proceed northward, we find one active volcano in Peru, but earthquakes are so common that scarce a week passes without them; and the names of Lima, and Callao, are familiar in this connection. Proceeding still farther north, the mountains increase in height, and furnish by the melting of their accumulated snows, and the moisture which is precipitated from the trade winds which blow over the warm region of Brazil, the sources of that magnificent river, the Amazon, which continually pours such a flood of water into the Atlantic. When we arrive in the neighborhood of Quito, in Equador, we find numerous and very lofty volcanoes, no less than six being embraced in a space of five degrees; commencing at the second degree of south latitude, and proceeding to the third degree of north latitude — One of these volcanoes, Cotopaxi, arises to the height of 18,867 feet, and is the highest volcanic summit of the Andes. In form it is a perfect cone, usually covered with an enormous bed of snow. On next page, we give an engraving which represents this celebrated volcano, which is higher than Vesuvius would be, if placed on the top of Teneriffe. The smooth cone, crested with the purest white, shines in the rays of the sun with dazzling splendor, and detaches itself from the azure vault of heaven in the most picturesque manner. At night, smoke and fire are seen rising from its summit, like a

beacon of flame in the regions above. In the course of the last century it had five great eruptions; in one of these, in January

1803, the snows were dissolved in one night, pouring a deluge of waters over the plains below. It is averred that the eruptions of Cotopaxi have been heard at a distance of 600 miles, and Humboldt states that at 140 miles distance on the coast of the Pacific, it sounded like thunder. The substances ejected from these lofty craters are pumice, and cinders, rarely lava currents; on account of their immense heights, and the consequent enormous pressure which is required to raise a solid molten mass. Torrents of mud and boiling water are erupted, and subterranean cavities containing water are opened, and vast quantities of mud, volcanic sand, and loose stones, are carried down to the regions below. Mud derived from this source, in the year 1797, descended from the sides of Tunguragua, a volcano in the neighborhood of Cotopaxi, and filled valleys 1000 feet wide to the depth of 600 feet. In these currents and lakes are thousands of small fish, which, according to Humboldt, have lived and multiplied in the subterranean lakes. So great a quantity of these fish were erupted in 1690, from the volcano of Imbaburu, that fevers were caused by effluvia arising from the putrid animal matter. Sometimes, after successive eruptions, the undermined walls of the mountain fall, and it becomes a mass of ruins, such was the fate of L'Altar, which was once higher than Chimborazo, but according to the tradition of the natives, before the discovery of America, a prodigious eruption took place which lasted eight years and broke it down.

In 1698 another lofty volcano fell, with a tremendous crash. Proceeding farther north, we find three active volcanoes in the province of Pasto, and three likewise in that of Popayan. Passing on, across the isthmus of Darien into Guatemala, and Nicaragua, no less than twenty-one active volcanoes are found between the tenth and fifteenth degrees of north latitude. Among these is an enormous mountain called the volcano of water *(de Agua)*, at the base of which in 1527, the old city of Guatemala was built. A few years afterward, a most formidable aqueous eruption burst forth, which overwhelmed the whole city, and buried in the ruins most of the inhabitants. Appalled by this disaster, the Spaniards built another city, New Guatemala, in another situation, farther from the mountain. Among other splendid buildings it contained a Cathedral more than 300 feet long, and one of its nunneries had more than 1000 persons in it. After a series of dreadful shocks, and volcanic eruptions, this beautiful city shared the fate of the former, and was reduced to a heap of ruins in 1775. We have now traced this volcanic chain for a distance of nearly 5000 miles from south to north, arriving at the high table land of Mexico, which is the middle part of the great chain of mountains called the Andes or Cordilleras in the south, and the Rocky Mountains in the north. This table land is from 6000 to 8000 feet in height, thus rivalling Mount St. Bernard and other remarkable summits in the eastern continent. This table land is not an interval between opposite ridges, but is the highest part of the ridge itself. In the course of it, isolated peaks occur, the summits of which reach the elevation of perpetual snow. It is somewhat remarkable, that a chain of volcanic mountains traverses this table land at right angles, which, with few interruptions, seems almost as smooth as the ocean, to a distance of 1500 miles north. Hence while communication with the City of Mexico is very difficult from either sea coast, there is nothing to prevent wheel carriages from running along the top of this mountain chain to Santa Fe. The volcanic mountains, are five in number, and run at right angles; commencing with the most eastern, we have Tuxtla, a few miles west of Vera Cruz; Orizava, the height of which is 17,370 feet; Popocatepetl 500 feet higher, and shown in the engraving below.

This is the highest mountain in Mexico, and is continually burning. The two others lie on the western side of Mexico, and are

called Jorullo and Colima, the latter being 9000 feet in height. We shall have occasion to speak of Jorullo and its eruptions hereafter. It is somewhat remarkable that these five volcanoes now active, are connected by a chain of intermediate ones, which undoubtedly have been so at some remote period, and that if the line of volcanic vents be prolonged in a westerly direction, it will pass through a group of volcanic islands, called the isles of Revillagigedo. Proceeding north of Mexico, another chain of mountains running parallel with the Rocky Mountain chain, commencing in the peninsula of California, runs as far north as the 50th deg. of north latitude, where it ends near the Rocky Mountains. In the peninsula of California there are three, or according to some accounts, five active volcanoes. In the Rocky Mountain chain from Mexico north, no active volcano occurs, but the whole country, says Mr. Parker, "from the Rocky Mountains on the east and Pacific Ocean on the west, and from Queen Charlotte's Island on the north to California on the south, presents one vast scene of igneous or volcanic action. Internal fires appear to have reduced almost all the regular rock formations to a state of fusion, and then, through fissures and chasms of the earth, to have forced the substances which constitute the present volcanic form. Such has been the intensity and extent of this

agency, that mountains of amygdaloid and basalt have been thrown up; and the same substance is spread over the neighboring plains, to what depth is not known; but from observations made upon channels of rivers and the precipices of ravines, it is evidently very deep. The tops of some mountains are spread out into horizontal plains, some are rounded like domes, and others terminate in conical peaks and abrupt eminences of various magnitudes, which are numerous, presenting themselves in forms resembling pillars, pyramids, and castles. There are several regularly formed craters; but these, presenting themselves in depressions or in cones, are rendered obscure by the lapse of time." Mr. Parker also states that nearly all the rocks of this region are amygdaloid, i. e. a trap rock in which agates and mineral substances are scattered about like almonds in a cake; basalt, lava, and volcanic glass, or obsidian. The Rocky Mountain chain extends north to the Arctic ocean, skirts along its coast, and is probably connected subterraneously, with the volcanic band which we shall presently describe, extending from the Aleutian Isles, or extremity of the peninsula of Alaska, in Russian America, to the Molucca Isles. The whole shore of western America, from the peninsula just mentioned to Vancouver's Islands, presents a bold and awful aspect, being bordered with mountainous steeps, covered with primeval forests, and containing two of the most elevated peaks in the northern part of America, Mount St. Elias, 18,000 feet, and Mount Fairweather, 14,913 feet above the ocean. Passing from the peninsula of Alaska, we find the volcanic chain extending through the Aleutian or Fox Islands, which are a long and numerous group extending nearly to Kamschatka. From almost every island, steep and lofty peaks arise, and from many, volcanic fire is discharged. In 1795 an island was thrown up and added to this group, by an eruption from beneath the sea, and continued to increase, till in 1807 it measured twenty miles in circuit. Throughout this whole tract, earthquakes of the most terrific description occur. The line of volcanic craters continues through the southern extremity of Kamschatka, where are seven active volcanoes, which in some eruptions have scattered ashes to immense distances. The chain is prolonged through the Kurile

islands, where a train of volcanic mountains exists, nine of which are known to have been in eruption; and elevations of the bed of the sea from earthquakes have occurred several times since the middle of the last century. The line is next continued through the Japanese group, which contains a number of active volcanoes and is continually liable to earthquakes. Proceeding southward, the chain is continued through the islands of the East Indian Archipelago. Mountain ranges of a volcanic character traverse almost all these, some rising upwards of 12,000 feet in height. In Sumatra, four volcanoes occur, and also several in Java. The largest of the Mollucca group, Celebes, contains a number of volcanoes in a state of activity, and one of the most terrible eruptions ever recorded happened on the island of Sumbawa another of this group. Here the chain branches off eastward and westward, passing to the west through New Guinea, New Britain, the Solomon group, and the New Hebrides, thence through the Friendly and Society Islands nearly east. Indeed the Pacific Ocean in the equatorial regions seems to have been one vast theatre of igneous action, its innumerable archipelagos being composed of volcanic rocks, or coralline limestones with active vents here and there. To the westward, the chain passes through Borneo, and Sumatra, to Barren Island in the Bay of Bengal. From Java southward, the chain may be traced along the coast of New Holland and Van Diemens land, and thence probably is a submarine connection with Freeman's Peak, in the Balleny Isles, on the Antarctic continent. Still farther south we have the chain extending along Victoria land, between 80° and 70° of south latitude, connecting with Mounts Erebus and Terror before mentioned. Another great chain of mountains runs nearly east and west from the shores of the Caspian sea to the Atlantic, passing through Turkey, Austria, Italy, Switzerland, France, and Spain. The whole region along this chain, which sends off many lateral branches, is subject to earthquakes and other volcanic phenomena; the well known volcanoes Etna, and Vesuvius, are a part of this chain. In addition to the volcanic chains we have named, there are some cases of isolated volcanic action, such as Mount Hecla in Iceland, and the volcanoes of Madagascar.

CHAPTER VII.

Volcanic Eruptions.

"But, even then, the ground
Heaved 'neath their tread — the giant turrets rocked,
And fell: and instantly black night rushed down,
And from its bosom burst a thunderous crash
Stunning and terrible." *Wm. Howitt.*

The number of active volcanoes, and solfatares or vents, from which sulphureous and acid vapors and gases are given off, is about 305; of these, 196 are in islands, and the other 109, are on continents. It is however, a remarkable fact that a majority of them are located near the ocean, or large bodies of water; and even submarine volcanoes are not of unfrequent occurrence. Besides the volcanoes now in action, there are many undisputable extinct volcanoes, *i. e.*, volcanoes which at some period of the earth's existence, but before the historic era, have been in the state of active eruption. In no country is there better evidence of this than in France. There are in the districts of Auvergne, Vivarais, and Cervennes, more than a hundred conical mountains, composed of lava, scoriæ, and volcanic ashes heaped up, many of them still retaining their ancient craters, and in some cases currents of lava may be traced to great distances. The evidences of volcanic action in the Rocky Mountains we have already alluded to.

How long a period of repose may be necessary to constitute an extinct volcano, is of course undetermined. We include as such, those which show indubitable evidence of former activity, but which have not had eruptions within the historic era. It is by no means necessary that volcanoes, to be considered active, should incessantly emit flames, they may remain for ages choked up,

and again suddenly resume all their former character. Thus Vesuvius, which had been extinct from time immemorial, although its crater was clearly formed by some ancient volcanic action; suddenly rekindled in the reign of Titus, and buried the cities of Herculaneum, Pompeii, and Stabiæ, under its ashes. After this effort it again slumbered, the memory of its former power faded away; trees and grass grew on its summit, when suddenly in 1630, it renewed its action. At this time, the crater, according to the account of Bracini, who visited Vesuvius not long before the eruption of that year, "was five miles in circumference, and about a thousand paces deep; its sides were covered with brushwood, and at the bottom there was a plain on which cattle grazed. In the woody parts wild boars frequently harbored. In one part of the plain, covered with ashes, were three small pools, one filled with hot and bitter water, another salter than the sea, and a third hot but tasteless." Suddenly, in December 1630, these forests and grassy plains were blown into the air, and their ashes scattered to the winds; seven streams of lava poured at the same time from the crater, and overflowed several villages at the foot, and on the side of the mountain; since that time there has been a constant series of eruptions. Etna after slumbering for ages, burst forth and destroyed the city of Catania; the accounts of its previous eruptions having been considered by the inhabitants as fables.

Subterranean noises, and the appearance, or increase of smoke, are the first symptoms of approaching volcanic action. This is soon accompanied by a trembling of the earth, and louder noises; the air darkens, and the smoke, thick with fine ashes, increases. The stream of smoke rises like an immense black shaft, high up into the air, and arriving at a point where its density is the same as the atmosphere, spreads out like a vast umbrella, overshadowing the whole country with its dark gloom. Such was the appearance as described by Pliny, the Elder, who witnessed the eruption of Vesuvius which overwhelmed Pompeii, in A. D. 79. Occasionally, lightning flashes illuminate the dark cloud, and streams of red hot sand, like flames, shoot up into the sky, attended with loud explosions. The shocks, and tremblings of the

ground, increase, and the whole neighborhood gives evidence of the immense pressure which is being exerted; presently the molten lava, is by the immense force raised into the crater, and filling it up, or melting its passage through the side, flows in a red hot stream down the flanks of the mountain in a river, or rather a torrent of fire. The eruption is sometimes attended with enormous currents of water, mud, and noxious gasses. A period of rest succeeds, generally of short duration; again the same phenomena are repeated, and thus the action continues for a variable length of time, until finally, the crisis is past and the volcano resumes its original quiet.

The substances principally ejected by volcanoes are smoke, ashes, sand, scoriæ, volcanic glass and bombs, and masses of rock. The ashes thrown out in volcanic eruptions appear to be the substance of the lava very finely divided. These ashes are raised so high that they are carried by the winds to almost incredible distances. Ashes from the eruption of a volcano in St. Vincent in 1812, were carried twenty leagues, and fell in Barbadoes, and from the eruption of Hecla in 1766, they fell in Glaumba, a distance of fifty leagues; and it is said that ashes from Vesuvius have fallen in Constantinople, a distance of four hundred and fifty leagues. The volcanic sand, is composed of particles somewhat larger, but of the same character as the ashes, being comminuted particles of lava, and forming a principal part of the ejected matter of volcanic eruptions. Scoriæ, and pumice stone, are caused by the gasses, which bursting through the melted lava, carry up with them certain portions into the atmosphere, which becoming consolidated, present the appearance so well known under the name of slag and cinders. Volcanic glass or obsidian, is often ejected in small melted masses; sometimes, the winds catching this, spin it into the finest threads. We have seen many specimens of this kind from the eruptions of Kirauea, in the Sandwich Islands. Among the extinct volcanoes of France, drops, tears, and elongated spheroids, being drops of lava thrown out, and consolidated in the air, are continually found, they are called volcanic bombs. Masses of rock are always ejected in severe eruptions; in many cases these are undoubtedly torn off

from the interior of the mountain by the immense power exerted; and they are ejected without having been melted. A stone of 109 cubic yards in volume, was ejected by Cotopaxi, and thrown to a distance of nine miles.

The force which is exerted, to cause the eruptions of lavas, or liquid masses of stone, is almost beyond belief, varying according to the height of the crater. The force of Vesuvius in some of its eruptions has been estimated as equivalent to a pressure of at least 6000 pounds on every square inch; and of Etna, about 17,000 pounds on the square inch; the amount of force requisite to raise melted lava to the crater of Cotopaxi, would be at least 30,000 pounds on each square inch. The masses of melted matter ejected, are equally incredible; the amount thrown out by Vesuvius in 1737, was estimated at 11,839,168 cubic yards, and about twice this amount in 1794. In 1660, the mass of matter disgorged by Etna, according to Mr. Lyell, was twenty times greater than the whole mass of the mountain, and in 1669, when 77,000 persons were destroyed, the lava covered 84 square miles. The greatest eruption of modern times, was from Skaptar Jokul, in Iceland, in 1783. Two streams of lava, one fifty miles long and twelve broad, the other forty miles long, and seven broad; both avaraging 100 feet in thickness, and sometimes 500 or 600 feet, flowed in opposite directions, destroying twenty villages, and 9000 inhabitants. The velocity with which the melted lavas move varies with the slope of the mountain, and the nature of the ground, as well as the viscidity and quantity of the lava. In general, a velocity of 400 yards an hour is considered quick, although sometimes the stream flows much quicker; in flat grounds it sometimes occupies whole days in moving a few yards. Lavas cool extremely slow, the surface becomes soon consolidated, and is such a poor conducter of heat, that the interior remains heated and melted for whole years; and currents have been mentioned which were flowing ten years after emerging from the crater, and they have been seen smoking twenty years after an eruption of Etna. The currents of lava thrown out by successive eruptions being placed one above the other, alternating with beds of sand, scoriæ, &c., form a series of inclined beds that give rise to the cone of the mountain.

Having now described the principal phenomena attending volcanic eruptions, and the nature of the erupted materials, we proceed to describe briefly some of the more remarkable effects of volcanic agency. Southern Italy, being inhabited by a cultivated people, and in very early times the seat of literature and science, as well as the grand European seat of volcanic action, claims particular attention. Here are three active volcanic vents. Vesuvius near Naples, Stromboli on the Lipari Isles, and Etna in Sicily. The whole region is subject to earthquakes, and abounds in thermal springs impregnated with calcareous matter, and from certain fissures deleterious gasses and sulphureous flames issue. The ancient name of Vesuvius, was Somma; it is now a broken and irregular cone about 4000 feet in height. We have already given the description of this mountain as it appeared before the eruption of 1631. It is said that its cone was formerly of a regular shape, with a flat summit, containing the remains of an ancient crater, and covered with wild vines. After a slumber of ages, Vesuvius in the year 63, began to exhibit some symptoms of internal agitation, by an earthquake which occasioned considerable damage to some of the neighboring cities. It is somewhat remarkable that the memorials of this convulsion have been preserved, and made known, through the agency of another more terrible convulsion, that of August 24th in the year 79, when a tremendous eruption occurred, and the pent up melted materials of the volcano burst out, overwhelming three cities and many of their inhabitants. Two of these cities, Herculaneum, and Pompeii, have since been exhumed. The former was first discovered; but they had long been forgotten. The eruption which destroyed these cities was witnessed by both the Plinys, and indeed, it was from his too venturesome curiosity to observe this magnificent natural exhibition, that the elder Pliny lost his life, being suffocated by the sulphureous vapors. The account which Pliny the Younger has left of this eruption, is very full and minute; but he makes no allusion to the overwhelming of the two cities. In 1713, Herculaneum was accidentally discovered, having been buried in lava for 1634 years. Some fragments of marble were observed in sinking a well; and subse-

quently a small temple, and some statuary. The city of Portici is built upon the lava directly above Herculaneum, and this has prevented extensive excavations. Pompeii was enveloped in ashes and cinders, and has been opened to the light of day. Both these cities were sea-ports, and Herculaneum is still near the shore, but Pompeii is at some distance, the intervening land having been formed by volcanic agency. In both these cities inscriptions were found in the temples commemorating the event of their rebuilding after having been overthrown by an earthquake sixteen years before, A. D. 63. Thus, in the language of Bulwer, "After nearly seventeen centuries had rolled away, the city of Pompeii was disintered from its silent tomb, all vivid with undimmed hues; its walls fresh as if painted yesterday; not a tint faded on the rich mosaic of its floors; in its forum the half-finished columns, as left by the workman's hand; before the trees in its gardens the sacrificial tripod; in its halls the chest of treasure; in its baths the strigil; in its theatres the counter of admission; in its saloons the furniture and the lamp; in its triclinia the fragments of the last feast; in its cubicula the perfumes and rouge of faded beauty; and everywhere the skeletons of those who once moved the springs of that minute, yet gorgeous machine of luxury and of life."

We here present a view of Vesuvius from Sir Wm. Gells Pom-

peiana, showing the site of Pompeii, and the course of the river Sarnus. Among the ruins of these cities many valuable relics have been found. The various utensils and works of art, almost as fresh as though buried but for a day. Rolls of papyri, with little tickets attached, denoting their contents; loaves bearing the stamp of the baker; linen, and fish-nets, and fruits, all preserved along with sculptures, and paintings, and unharmed for near 2000 years. No doubt, many valuable manuscripts will be found when Herculaneum is more excavated, which will restore to us the lost writings of the ancient philosophers. The eruption of Vesuvius which buried these cities, is so well known we need not dwell longer upon it here; we pass to consider next the eruptions of Etna.

The cone of Etna, which has been so minutely and well described by Mr. Lyell, is entirely composed of lavas, and rises majestically to an altitude of two miles, the circumference of its base being about 180 miles. At the base of the mountain is a delightful, well cultivated and fertile country, thickly inhabited, and covered with olives, vines, corn, fruit trees, and aromatic herbs. Higher up, upon the mountain side, a woody belt encircles it, forming an extensive forest of chesnut, oak, and pine, with some groves of cork and beech, and affording excellent pasturage for flocks; still higher up, is a bleak barren region, covered with dark lavas and scoriæ. Here, from a kind of plain arises the cone of Etna to the height of 11,000 feet, and continually emits sulphureous vapors; its highest points being covered with eternal snow. Over the flanks of Etna a multitude of minor cones are distributed, particularly in the woody tract, caused by former eruptions, but the grandest feature of Etna is the *Val del Bove*, which is a vast excavation, as though a portion of the mountain had been removed on the side towards the sea, forming a vast plain, five miles across, encircled by minor volcanic cones, and enclosed on three sides by precipitous rocks from 2000 to 3000 feet high. This vast plain has been repeatedly deluged by streams of lava, and presents a surface more rugged and uneven than that of the most tempestuous sea. From the earliest period of history, Etna appears to have been active, but the first great

eruption of modern times occurred in the year 1669. Previous to this eruption, an earthquake occurred which levelled many of the villages and towns in the neighborhood, and was attended with an extraordinary phenomenon. A fissure, six feet broad and of unknown depth, opened with a loud crash in the plain of St. Lio, and run to within a mile of the summit of Etna, in a somewhat tortuous course. Its direction was from north to south, and it emitted a most vivid light. Five other parallel fissures of considerable length, afterwards opened, one after another, attended with similar phenomena. Mr. Lyell supposes that these were, at the time, filled with melted trap or porphyry, forming vertical dikes. During this eruption a minor cone known by the name of Monti Rossi, was formed, about 450 feet high, which poured out a lava current, which after overflowing some fourteen towns and villages, some having a population of 3000 to 4000 inhabitants reached the city of Catania, ten miles distant from the volcano. Walls sixty feet high had been purposely raised to protect the city in case of eruption. Against this rampart the lava flowed, and accumulated, until in a fiery cascade, it poured over the top, and destroyed a part of the city. The wall still remains, and the curious traveler may see the lava curling over the top, by means of excavations since made, as if still in the very act of falling. This lava current moved a distance of fifteen miles before it reached the sea. One of the towns overflowed during this eruption was Mompiliere, a part of which, was afterwards uncovered with incredible labor, and the gate of the principal Church was reached at a depth of thirty-five feet, and several articles in good preservation were extracted, among these were a bell, a statue, and some coins. It is said that the heat of this lava current was so intense eight years afterwards, that it was impossible to hold the hand on some of the crevices formed by the cracking of its crust upon cooling. In the year 1828 a remarkable discovery of a glacier covered by a lava stream was made, after having been concealed for ages. In that year, from the protracted heat of the season, supplies of ice at Catania and the adjoining parts of Sicily, failed entirely, and great distress was felt at the want of a commodity which they had learned to regard as

a necessary of life; accordingly search was made at a place which had long been suspected as being a glacier covered with lava, at the foot of the highest cone, when for several hundred yards a solid bed of ice, so hard that it was quarried with the utmost difficulty was found, covered entirely by lava.

We now turn to Iceland, an island subject to tremendous volcanic eruptions, and containing several volcanic mountains. Mount Hecla has been in continual activity, with but a short occasional rest, from the earliest period; its eruptions have lasted sometimes as long as six years without cessation. In the year 1783 two great eruptions happened, about a month apart, one about the middle of May, and the other the 11th of June. The first was a submarine volcano which threw up so much pumice that the ocean was covered to a distance of 150 miles. A new island was formed, consisting of high cliffs, within which, fire, smoke, and pumice, were emitted from several different parts. This island, which, was claimed by His Danish Majesty and called Nyoe, or new-island, was destroyed before a year, by the sea, leaving nothing but a reef of rocks from five to thirty fathoms under water. The eruption of June 11th was on the island, a distance of 200 miles from Nyoe, when the crater of Skapta Jokul emitted a torrent of lava which flowed down into the river Skapta, and entirely dried it. This river was about 200 feet in breadth and from 400 to 600 feet deep, running between high rocks, not only was this great bed filled with the lava current, but, rising higher, it overflowed the neighboring fields; after filling the bed of the river, the lava current flowed into a deep lake, which was in a short time completely filled; still flowing on, it penetrated the caverns which had been formed in the older lava, and melted down portions of it, and in some cases where it could not get vent, it blew up the rock with a tremendous explosion. On the 18th of June another ejection of melted lava, flowed with great swiftness down the mountain, over the bed of the former eruption. By the damming up of the rivers, and lakes, and consequent displacement of water, many villages were completely destroyed and overwhelmed. This lava current, after flowing for several days, was finally precipitated down a tremendous catar-

act called Stapafoss, filling up a profound abyss which the water had been hollowing out for ages. On the 3rd of August another flood of lava was poured forth which flowing in an entirely new direction, as all the other channels were choked up, filled the bed of the river Hverfisfliot, occasioning great destruction of property and life. The eruption continued for about two years, and eleven years afterwards when Mr. Paulson visited the island, he found columns of smoke still rising from parts of the lava, and several rents filled with hot water. Iceland at this time contained about 50,000 inhabitants, more than 9000 of whom perished during these eruptions, besides vast numbers of cattle; and twenty villages were destroyed, not enumerating those inundated by water. The great loss of life was owing not only to the vast amount of noxious gasses emitted, but to the famine caused by the showers of ashes throughout the island, and the desertion of the coasts by the fish. The two branches of lava which flowed during this eruption, in opposite directions, were, the one fifty, the other forty miles in length, and their average depth 100 feet. The extreme breadth of the current which filled the bed of the river Skapta, was twelve miles, the extreme breadth of the other was about seven miles. The eruptions of Hecla, six of which have occurred in one century, seem now to be suspended, but the whole island presents abundant evidence of volcanic action. We have already alluded to the phenomena of the Geysers, or hot springs; beside these there are no less than six volcanic vents, emitting flame and smoke. The island of Nyoe thrown up just before the great eruption of Skapta Jokul, is by no means the only instance of a volcanic island occurring at a recent period. In the year 1831, a volcanic island arose in the Mediterranean, about thirty miles off the south-west coast of Sicily, in a spot which had been found by Capt. Smyth to be more than 600 feet in depth. On the 28th of June, Sir Pultney Malcolm, in passing over the spot with his ship felt the shock of an earthquake, as if he had struck on a sand bank, this was about a fortnight before the eruption occurred. About the 10th of July a Spanish Captain who was passing near the place, reported that he saw a column of water, like a water spout, about sixty feet in height, rising from the sea; this was

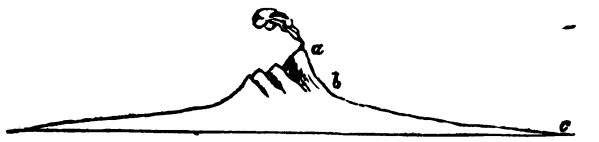
succeeded by a cloud of steam, and at length, on his return, the 18th of July, he found a small island about twelve feet high, with a crater in its centre, ejecting scoriæ, ashes, and volumes of vapor; and the sea around was covered with floating cinders, and dead fish. This island continued increasing in dimensions until it reached an elevation of 200 feet, and was about three miles in circumference, having a circular basin full of hot water, of a dingy red color. The eruption continued with great violence nearly a month, and the island attained its greatest dimensions about the 4th of August, after which it began to decrease by the action of the waves, and on the 29th of September, its circumference was reduced to about 700 yards. Its appearance at this time is represented in the accompanying wood cut, which is from a sketch

by M. Joinville, who visited this island in September 1831. It has now entirely disappeared, and a dangerous shoal remains about eleven feet under water. This is not the only volcanic island of recent formation, for in the year 1812, off the coast of St. Michael's one of the Azores, an immense volume of smoke, thick with ashes and stones, was observed to burst forth, by Capt. Tillard, of the Royal British Navy, at a spot where before, the

water was thirty fathoms in depth. At the same time the cliffs of St. Michæl were shattered by an earthquake. This island, which was called Sabrina, from the ship of Capt. Tillard, rose 200 feet above the water, but soon after disappeared being composed almost entirely of ashes and cinders. We have already noticed the Aleutian islands, as the theatre of volcanic action. In the year 1806, a new island, which still remains, and consists of solid rock, about four miles in circumference, was thrown up from the bottom of the sea; and in 1814, another of the same character, but much larger, being 3000 feet in height, was added to the same group. We might enumerate many other islands formed by volcanic agency did our limits permit, but we hasten to consider next the volcanoes of South America.

In noticing the great chain of mountains which runs along the western coast of America, we alluded to the five volcanic vents in about the parallel of the City of Mexico, arranged in a line at right angles nearly to the general direction of the mountainous chain. One of these volcanoes, that of Jorullo, is particularly remarkable, being the product of an eruption which occurred in 1759, and lasted about nine months. The volcanoes of Tuxtla, Orizava, and Popocatapetl, are on the eastern side of Mexico, the latter is continually burning, but seldom emits anything more than smoke and ashes. At the west of the city, are the volcanoes of Colima, and Jorullo, the former about 9000 feet in height, and emitting smoke and ashes; between the city and this volcano lies the plain of Jorullo, in which a crater was formed in 1759. In that year according to Humboldt, who has minutely described the phenomena, in the month of June, a subterranean noise was heard in the district of Jorullo; hollow sounds of the most frightful nature, which were accompanied by frequent earthquakes, succeeded each other for from forty to fifty days; causing great terror to the inhabitants of that district. From the beginning of September everything seemed to announce the complete re-establishment of tranquility, when, in the night of the 28th and 29th, the horrible subterranean noise recommenced. The affrighted Indians fled to the mountains, soon a tract of ground, from three to four square miles in extent, began to swell like waves

of the sea, and finally rose up in the shape of a bladder, then opened, and fragments of burning rocks accompanied with flames, were thrown to an immense height. The rivers Cuitimba and San Pedro, which watered this plain, formerly cultivated with fields of cane and indigo, precipitated themselves into the burning chasms. Hundreds of small cones from three to ten feet high, called by the natives *hornitos* issued from the smoking plain, and six large volcanic cones were formed, the smallest three hundred feet high, and the largest, which is the present volcano of Jorullo, 1600 feet in height. It is continually burning, or rather now sending forth sulphureous gasses, and has thrown up from its north side immense masses of basaltic lava, with fragments of granitic rocks. Below we give an outline of this celebrated vol-



canic mountain, *a* is the summit of Jorullo, *b c* inclined plane, sloping at an angle of 6° from the base of the cones. This eruption occurred at a distance of 150 miles from the sea-coast, and is somewhat remarkable on this account, all other active volcanoes being near the sea. The eruptions of mud, however, and balls of decomposed basalt, and especially strata of clay, seem to indicate that subterraneous water had no small share in producing this phenomenon. Humboldt visited the country more than forty years after the eruption, and found the elevated mass of the former plain, shown by the slope *b c* in the preceding outline sketch, still hot enough in some of the fissures at a depth of a few inches, to light a cigar. The *hornitos* have now ceased to emit steam, or smoke, and the central volcano is itself almost extinct, the plain and slope of the mountain is covered with a luxurious vegetation, and the memory of the former terrific convulsions seems almost forgotten.

We have now given an account of the most celebrated volca-

noes, and the effects produced by their eruptions. When we bear in mind that during the earlier periods of the earth's existence, volcanic action was much more general and severe than at present, we will be at no loss for a sufficient cause to produce most of the upheavings, and contortions of strata, observed on our globe. In some parts of the world, whole districts are composed of extinct volcanoes, which even yet have not wholly ceased to emit deleterious gasses, and the traces of their former and powerful action are seen in every country.

We have not discussed at all, the causes which produce volcanic eruptions; these are not yet satisfactorily determined; and a great diversity of opinion still exists among philosophers. It will be seen upon referring to the diagram, (page 178), that the comparative height of the loftiest mountains, is but as a minute grain of sand on a large globe, and that such slight changes from the general level of the surface may be produced by causes comparatively small.

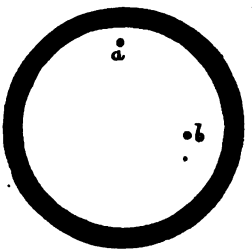
CHAPTER VIII.

Earthquakes.

"Of chance or change, oh! let not man complain;
Else shall he never, never, cease to wail;
For from the imperial dome, to where the swain
Rears his lone cottage in the silent dale,
All feel the assault of fortune's fickle gale.
Art, empire, earth itself, are doom'd;
Earthquakes have raised to heaven the humble vale;
And gulfs the mountains' mighty mass entomb'd;
And where the Atlantic rolls, wide continents have bloom'd."
Beattie.

In the present chapter we shall briefly describe some of those remarkable convulsions which from time to time have caused the crust of the earth to heave like the waves of the ocean, and to gape open in many places, suddenly engulphing cities and their inhabitants, or deluging whole tracts of country by the upheaved waters. These phenomena, which are supposed to be caused by immense evolutions of steam, and other vapors, or gasses, under an intense pressure, which is only relieved by a volcanic eruption, or an opening of the earth, constitute the most terrible warnings, which reminds us of the instability of all things. The evidences of mighty change which the philosopher sees in each upheaved hill of granite, and dike of trap, or in the formation of contorted strata may read to him a lesson, which, if rightly understood, will teach him to look far from his present abode, for the unchangable world; but the careless observer, who builds his cottage on the side of a volcanic cone, and feeds his flocks within its crater, needs the awful sound of subterranean thunder, and the rocking of the plain, to convince him that the neglected traditions of former calamities, were not all a fiction.

There is something startling in the idea that our earth, or rather its crust, is perhaps but a few hundred miles in thickness, or in other words, that our globe is a hollow ball of no very great dimensions. It is a well established proposition that, under influence of the attraction of gravitation, a body, or a mass of matter, placed any where within a hollow globe, as at *a* or *b*, (see the diagram below), will remain at rest wherever it may be situated.



Hence, whether the interior of the hollow globe be molten or not, the mass will not be displaced, or in other words, it will have no tendency to move, unless operated upon by other force than the attraction of gravitation.

The name earthquake has been given to those convulsions of supposed igneous origin, which cause the surface of the earth to heave, or undulate, producing rents, and generally precursing the eruption of some volcano. The region of violent earthquakes, is generally the site of some active volcano, and the paroxysms of an earthquake, are generally relieved by a volcanic eruption. Thus, during the earthquake which overturned Lima in 1746, and which was one of the most terrible which has been recorded, four volcanoes opened in one night, and the agitation of the earth ceased. The phenomena attending earthquakes are various, sometimes there is but a slight undulatory movement, barely sufficient to cause the lighter articles upon the surface to change places. Persons unacquainted with the phenomena of earthquakes, suppose themselves seized with a sudden giddiness. Often the first shocks are of this light character, then gradually be-

come more severe, and frequent, so that the movement of the earth is apparent to the most inexperienced. It is now that the subterranean thunder is heard, and the walls of buildings begin to gape open, and close, rendering it exceedingly dangerous to remain in them. The fields and the mountains, at such times, afford no secure shelter, the former are often rent asunder, opening enormous fissures, which engulph thousands, and then close again, while the mountains are rent, and slide down into the valleys, damming up the rivers and lakes, and causing tremendous inundations. At such times, the bed of the ocean appears as unstable as the dry land; vast waves, sometimes fifty or sixty feet in height, are rolled along the coast, and then retire, leaving the whole shore dry. Ships at sea, often experience these extraordinary movements, even at a distance of 250 miles from land, seeming as violently agitated as though grating over a ledge of rocks, and suddenly striking on the ground, and often with such violence as to open the seams of the vessel. The duration of a single shock rarely exceeds half a second. In this short space of time, thousands of human beings have found a common grave, and whole cities have been swallowed up. The interval which elapses between successive shocks is variable; sometimes they succeed with considerable rapidity, and at other times happen after an interval of months, or even years. The first shock is not always the most violent, though in some particular regions of country, Syria, for example, the first catastrophe is always the most destructive; generally however, the second shock is more violent. The extent of country agitated by some great earthquakes is very remarkable; thus the momentary upheaving of the bed of the ocean, during the earthquake of 1755, which destroyed Lisbon, caused the sea to overflow the coasts of Sweden, England, and Spain, and the islands of Antigua, Barbadoes, and Martinique, in America; at Barbadoes, the tide rose nearly 18 feet above high water mark, and the water was black as ink from the presence of bituminous matter. On the 1st of November, when the concussions appeared most violent, the water at Guadalope retreated twice, and on its return rose in the channel of the island 10 or 12 feet in height. A wave of the sea, 60 feet

high, overflowed a part of the city of Cadiz; and the lake of Geneva was observed to be in commotion six hours after the shock; agitations were also noticed on lake Ontario. Such is the great extent of country influenced by these terrible convulsions when exhibited in their most destructive form, but the changes which are silently being accomplished, the gradual elevations and subsidences of the land are no less remarkable. Previously to noticing these however, we will allude for a moment to similar phenomena but accomplished suddenly. In the year 1772, during an eruption of one of the loftiest mountains in the island of Java, a part of the island, and of the volcano, embracing a tract of country fifteen miles long, and six miles broad, was swallowed up, and in 1775, during the eruption which destroyed Lisbon, a new quay, upon which thousands of the affrighted inhabitants had congregated, suddenly disappeared, and not one of their bodies ever rose to the surface. In 1692, a tract of land a thousand acres in extent, in the island of Jamacia, sank down in less than a minute, and the sea took its place. On the 16th of June 1816, a violent earthquake happened at Cutch, in Bombay, which so much altered the eastern channel of the Indus, that from having been easily fordable, it was deepened to more than eighteen feet at low water, and the channel of the river Runn which had sometimes before been almost dry, was no longer fordable except at one place; and at the same time the mud village and fort of Sindree, belonging to the Cutch government, and situated where the Runn joins the Indus, was submerged, leaving only the tops of the houses above the water. But the subsidence of land caused by earthquakes is not more remarkable than the elevation, and many examples might be given of the upraising of land. Perhaps the most remarkable was during the terrible earthquake in November 1822, which agitated the western coast of South America in the vicinity of Chili, for a distance of twelve hundred miles from north to south. On examining the district around Valparaiso the morning after the shock, it was found that the entire coast for upwards of one hundred miles was raised above its former level, thus leaving dry the bed of the sea. The area of the surface upraised, and which extended from the sea coast to the

foot of the Andes, was estimated at one hundred thousand square miles. The rise upon the coast, was from two to four feet. In the year 1790 during several shocks, a space of ground three Italian miles in circumference, sank down near the town of Terranuovo, on the south coast of Sicily. Such are some of the immense changes effected during violent earthquakes. Numerous examples of immense rents, and sinking down of mountains might be cited did our limits permit, enough however, has been adduced, to show that the force which is sometimes generated far beneath the present surface of the earth, is almost beyond conception, far exceeding any pressure which human agency can produce.

The elevation and subsidence of various lines of coast, determined by water marks, but performed in a very gradual manner may be appropriately considered in this place. We commence with the beautiful Bay of Baiæ, which the researches of Lyell, Babbage, and other eminent philosophers have rendered a doubly classic ground. On the golden shores of this beautiful bay, some pillars and other fragments of an ancient Roman building were long known to exist. These were once supposed to be the remains of a temple dedicated to Jupiter Serapis, but the researches

of modern antiquaries have rendered it probable that these relics are the ruins of an extensive suit of baths. Three of the pillars

of this supposed temple, are yet standing, and are represented in the wood cut. These pillars are of marble, carved from a single block, and forty-two feet in height. One of the columns has a horizontal fissure extending nearly through it, the others are entire. All are slightly out of the perpendicular, leaning towards the sea. On these pillars, graven in marks too palpable to be misinterpreted, are characters which indicate that twice since the Christian Era the level of the land and sea has changed at Puzzuoli, and each movement, both of subsidence and elevation has exceeded twenty feet. The surface of these pillars is smooth for a distance of twelve feet from the pedestal, where a band of perforations made by a marine boring muscle or bivalve (*lithodomus**), commences and extends to a height of nine feet, above which, all traces of their ravages disappear. The holes are pear shaped, and in many of them shells are still found, notwithstanding the numbers carried off by curious visitors. The depth and size of these perforations indicate that the columns must have been submerged for a long time; for the hole, which is at first very small, and cylindrical, is enlarged by the animal as its size increases Besides these perforations there are incrustations effected by the agency of thermal springs in the neighborhood, and at varying distances, showing the gradual submersion. From all the facts which have been collected, we may prove pretty conclusively, as Mr. Babbage has done, that the temple, or rather baths, which was originally a building of a quadrangular form, seventy feet in diameter, the roof being supported by twenty-four granite columns, and twenty-two of marble, was built near the sea for convenience of the sea-baths, and also for the use of the hot spring which still exists on the land side of the temple; and that by the gradual subsidence of the land, a channel was formed, through which the salt water flowing and mingling with the thermal waters, a brackish lake was formed, producing an incrustation at various heights, of from three to four and a half feet, of a different character from what either would produce separately. After this, the land still subsiding, the channel which admitted the sea

* *Lithodomus*, from *lithos* a stone, and *domus* a house.

became choked by sand, tufa, and ashes, and also the area of the temple, and thus a lake of the waters of the hot spring was made the bottom of which would be very irregular, the proofs of this, are the incrustations of carbonate of lime, presenting a level surface above, but irregular below, and not covering the former incrustations. The land still continuing to subside, the sea again encroached, when the lithodomi, attaching themselves to the columns, and fragments of marble, pierced them in all directions, and this subsidence continued until the pavement of the temple was nineteen feet below the bottom of the sea. The base and lower portions of the temple being protected by the rubbish and tufa, and the upper, projecting above the water, prevented the ravages of the lithodomi, on those portions. The platform of the temple is now about one foot below high water mark, and the sea is forty yards distant. It is clear therefore, that they have long been submerged, and again elevated, moving each time a distance of twenty-three feet, and yet by so gentle a motion that the columns have not been overthrown. Not far from the temple is the solfatara or volcanic vent opened in the year 1198, after a series of earthquakes, and it is highly probable that during these earthquakes the land subsided, and the pumice and ashes ejected from the volcano falling into the sea protected the lower part of those columns which remained erect, from being bored by the lithodomi. The re-elevation was probably gradual at first, for we find in the year 1503, a deed from Ferdinand and Isabella, granting to the University of Puzzuoli "a portion of land where the sea is drying up;" but the principal elevation took place in 1538, when the volcanic cone of Monte Nuovo was formed, at which time, according to the accounts of eye-witnesses, the sea left the shore dry for a considerable space. Great as have been the changes of elevation and depression of the shores of the Bay of Baiæ, yet the movement has been so gentle as not to overthrow these ancient remains,

> "Whose lonely columns stand sublime
> Flinging their shadows from on high
> Like dials, which the wizard Time
> Had raised to count his ages by."

At the present moment the land is again subsiding and in the same gentle manner.

What was once deemed an encroachment, or rather a rise in the level of the sea, is now well understood to be but the movement of the coast, gently subsiding, this fact is well illustrated by the movement of land in Sweden, which is now, and has been for ages in course of elevation in some places, and depression in others, rising in the northern, and sinking in the southern parts. The proof of this great change, which had long been suspected, was complete upon examining the marks cut upon the rocks by the officers of the pilotage establishment of Sweden. It was found that in the space of fourteen years, the rise had been from four to five inches. The prevalence of marine shells, at some distance in the interior, of the same species as those now living in the neighboring seas, renders in highly probable that this rise has been going on for a long time, in certain portions of that country. The rocks of the coasts of Norway and Sweden, are principally gneiss, mica-schist, and quartz, and will retain their particular configuration or appearance unaltered for a long series of years, there seems therefore, but little room for any doubt as to the change of level of the land and sea, determined by the ancient landmarks, the appearance of new shoals, the elevation of the lines cut to mark the height of the water years previous, and the abundant occurrence of marine shells attached to the rocks at the distance of even fifty miles from the sea coast. From some phenomena occurring near Stockholm, it would seem that the land has been depressed and then re-elevated. In the year 1819, in digging a canal at Sodertelje, a place sixteen miles south of Stockholm, for the purpose of uniting Lake Maeler with the Baltic, at a depth of sixty feet, the workmen came upon what appeared to have been a buried fishing-hut, constructed of wood, it was in a state of decomposition, and crumbled away on exposure to the air. On the floor of the hut, which was in better preservation, was a fire-place composed of a ring of stones, within which were found cinders and charred wood, and outside were boughs of fir, still retaining the leaves and bearing the marks of the axe. Besides the hut, several vessels of an antique form were found,

having their timbers fastened together with wooden pegs, instead of nails, indicating their great antiquity. The situation of the hut seems only to be accounted for on the supposition of a change similar to that on the shores of the Bay of Baiæ, first subsiding to a depth of more than 60 feet, and subsequently being re-elevated. Examples of this gradual elevation are by no means rare. The coast of Newfoundland, in the neighborhood of Conception Bay, and probably the whole island is rising out of the ocean, at a rate which promises at no very distant period, materially to affect, if not render useless, many of the best harbors on its coast. At Port-de-Grave, a series of observations have been made, which undeniably prove the rapid displacement of the sea-level in the vicinity. Several large flat rocks, over which schooners might pass some thirty or forty years ago with the greatest facility, are now approaching the surface of the water, so that it is scarcely navigable for a skiff. Dr. Jackson describes a deposit of recent shells in clay and mud, with the remains of balani or barnacles, attached to trap rock twenty-six feet above the present high-water mark, on the margin of Lubec Bay in the State of Maine.

Changes like these which we have just described, have been of universal occurrence. Upon this subject Cuvier remarks, "The lowest and most level lands, when penetrated to a great depth, exhibit nothing but horizontal strata, consisting of various substances, almost all of them containing innumerable productions of the sea; similar strata, similar productions, compose the hills, even to a great height. Sometimes the shells are so numerous that they form, of themselves, the entire mass of the stratum. They are everywhere so completely preserved, that even the smallest of them retain their most delicate parts, their slenderest processes, and their finest points. They are found in elevations above the level of the ocean, and in places to which the sea could not now be conveyed by any existing causes. They are not only enveloped in loose sands, but are incrusted by the hardest stones, which they penetrate in all directions." Every part of the world, the continents, as well as all the islands of any considerable extent, exhibits the same phenomena; these animals have, therefore, lived in the sea, and the sea consequently must

have existed in the places where it has left them. Indeed, the proofs of elevation and subsidence, are everywhere too palpable to be mistaken. Stratified rocks, or rocks deposited by the agency of water, form the summits of the highest mountains, elevated many thousands of feet above the level of the sea. In these strata, the remains of shells, fishes, and other marine animals are imbedded. When in addition to this, we observe these strata not horizontal, but nearly vertical, we cannot resist the conclusion that they have either been violently upheaved by some tremendous convulsion, or gradually raised by the irresistable agency of a long continued subterranean force. The evidence of disturbance of the strata, afforded by certain marine worms is important, and is an instance of the subservience of the actions of even the meanest of created beings, to the elucidation of truth. It is well known that certain of these worms, inhabiting straight and tubular shells, bore the sand in a vertical direction, as represented in this figure, and if the strata remained undisturbed the

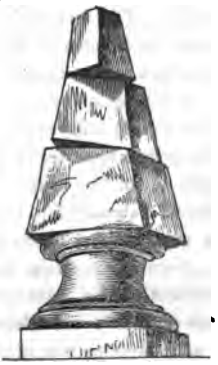
direction of the bore would be always vertical. But the shells are found in various strata, making various angles with the horizon according to the elevation of the strata, as shown in the figure below, and occasionally, a more recent shell will have the

vertical direction as at *a*, bering the cavity subsequently to the elevation of the strata. Beds of pebbles, once deposited in regular horizontal strata, are found making angles with the horizon, thus witnessing the same fact.

We will now briefly consider some of the most remarkable earthquakes which have occurred within the historic period. We commence with the well known one which nearly destroyed the

city of Messina in 1783. The shocks commenced on the 6th of February, and ended March 28th, though repeated at intervals for a space of four years. The full and interesting accounts of this convulsion, carefully prepared by scientific men, render this earthquake of much more importance to the geologist than many others which have occasioned infinitely more destruction of life and property, but of whose effect in changing the country we are almost entirely ignorant. The concussion of this earthquake was felt over a great part of Sicily, and the whole of Calabria, extending as far as Naples. The centre of the surface which suffered the most, was the small town of Oppido, in the neighborhood of Atramonte, a high, snow-capped peak of the Appenines. From this point, for a distance of twenty-five miles in all directions, nearly all the towns and villages were destroyed, and if we describe a circle with the same centre, having a radius of seventy-two miles, it will include all the country affected by this earthquake. The first shock, February 5th, threw down in the course of two minutes, the greatest part of the houses in all the cities, towns, and villages, from the western acclivities of the Appenines, (which traverse Calabria from north to south) in upper Calabria, to Messina in Sicily, convulsing the whole country. The granitic chain of mountains was slightly affected by the first shock, but more sensibly by those that followed; the principal shock being propagated with a wave like motion through the tertiary sands, sandstones, and clays, from west to east; and where the line of tertiary rocks joined the granite, the shocks were most severe, probably owing to the interruption of the undulatory movements of the softer strata by the harder granite, which prevented the passage of the shocks to the countries on the opposite sides of the mountain range. About 200 towns and villages were destroyed, more than one hundred hills slid down, fell together and damming up rivers, formed lakes. The quay at Messina sank down fourteen inches below the level of the sea. Deep fissures were caused at several places, and many subsidences, and upraisings of the ground took place, and the general features of the country were so altered that they could scarcely be recognised. Thus in a very short space of time the whole country was as

much changed as though it had been exposed to common influences a thousand years, and over 100,000 persons were destroyed. The movement of the ground was not only horizontal, but vorticose, at some places. This was shown by the partial turning of the stones of two obelisks at the convent of St. Bruno, in the small town called Stefano del Bosco, as exhibited in the wood cut below. The position of the stones was changed nine inches without their falling.



The most destructive and tremendous earthquake on record, is that which overthrew Lisbon in 1775. The first shock was on the morning of November 1st, about half past nine, when, without any other warning than a noise like thunder, heard underground, the foundations of this ill-fated city were violently shaken, and many of the principal edifices fell to the ground in an instant. Then with scarcely a perceptible pause, the rumbling noise changed into a quick rattling sound, resembling that of a wagon driven violently over the stones, this shock threw down every house, church, convent, and public building; overwhelming the miserable population with the ruins; it continued about six minutes. It is said by those who witnessed the effects of this earthquake, that the bed of the river Tagus appeared dry in many places, and boats sailing on the river were struck violently

as though they had run aground. Perhaps the most extraordinary circumstance which occurred during this earthquake was the subsidence of the new quay called *Cass de Prada*, built entirely of marble, and at an immense expense. A great concourse of people had fled to this quay, as a spot where they might be safe from the falling ruins, when suddenly it sank down, with all the people on it, and not one of the bodies ever rose to the surface, and a great number of boats, and small vessels, anchored at the quay were swallowed up with it, as in a whirlpool, no fragments of them ever appeared, and the water at the place of the quay has now a depth of upwards of 100 fathoms. At the time of the subsidence of the quay, the bar was seen dry from shore to shore, then suddenly the sea came rolling in, in a wave about fifty feet high. About noon there was another shock, when the walls of several houses, which the preceding shocks had not overthrown, were seen to suddenly gape open, and then to close again so exactly that no fissure or joint could be perceived. The extent of country affected by this earthquake is almost incredible. The movement was most violent in Spain, Portugal, and the north of Africa, but slighter shocks were felt from Greenland and Iceland, to Norway, Sweden, Germany, Britain, Switzerland, France, Morocco, Fez, and even in the West Indies; and on Lake Ontario in America. The rate at which the undulatory movement was propagated was about twenty miles a minute, judging from the interval of time when the shock was first felt at Lisbon and the time of its occurrence at other distant places.

In the year 1746, an earthquake occurred which overthrew Lima, in Peru, and inundated its port of Callao, so that only 200 out of 4000 persons escaped. Terrible as were these earthquakes yet they seem to have been inferior to some which have occurred at a more early date, in many parts of Asia. Earthquakes are by no means of uncommon occurrence, scarcely a year passes without several. They are now observed with great attention by philosphers, and are of the utmost importance in a geological point of view. Awful as it must appear to see the ground heaving and swelling like the troubled sea, hills tottering, and solid walls and towns tumbling into ruins, and the earth gaping open,

suddenly swallowing thousands of terrified men, women, and children, yet the philosopher looks beyond this sight of human suffering; forgetting the momentary pain and terror, he sees here the origin of many of those mighty changes which he had before detected, and learns many new facts in regard to the former physical structure and condition of our planet. We have now considered somewhat at length the aqueous, and igneous, causes of change in the inorganic world, and we proceed to consider the agency of the atmosphere and of vital action.

CHAPTER IX.

Atmospheric Causes of Change.

"The seas have changed their beds — the eternal hills
Have stooped with age — the solid continents
Have left their banks — and man's imperial works —
The toil, pride, strength of kingdoms, which had flung
Their haughty honors in the face of heaven,
As if immortal — have been swept away."

Henry Ware.

We have before described the atmosphere as an elastic fluid encompassing the earth, and capable of absorbing large quantities of moisture, and have illustrated the formation of clouds and the origin of winds. We can easily perceive that so important an agent may be capable of effecting the most marked changes, and we do not now allude to those effects produced by a secondary agency. Thus, the moisture deposited from the air in the form of rain, or snow, upon lofty mountains, causes deluges of water to descend and overflow the plains below, or becomes the source of those mighty rivers which roll through thousands of miles, bearing their immense deposits down to the ocean's bed. Changes like these we have already considered, and do not therefore include them in our present description. The atmosphere acts as an agent in destroying rocks and changing the face of a country, mechanically and chemically. The formation of immense dunes, or downs, which are heaps of blown sand, is an illustration of the former action, and the disintegration and destruction of rocks by the absorption of oxygen, and carbonic acid, is an example of the latter; both of these actions we will now briefly consider.

The fine sands of the African desert for a long series of ages, have been blown by the westerly winds over all the lands capable of tillage on the western banks of the Nile, involving in the

almost impalpable powder, ancient cities and works of art, except at a few places sheltered by the mountains. From the fact that these moving sands have only reached the fertile plains of the Nile in modern times, it was inferred by M. de Luc, that that continent was of recent origin. The same scourge he observes, would have afflicted Egypt for ages anterior to the time of history, had the continents risen above the level of the sea several hundred centuries before our era. But as Mr. Lyell very justly observes, there is no evidence that the whole African continent was raised at once, and it is possible Egypt and the neighboring countries might have been populated long before any sands began to be blown from the western portion, nor is there yet any evidence of the depth of this drift sand, in the various parts of the great Lybian deserts. Valleys of large dimensions may have been filled up, and may thus have arrested the progress of the sand drift for ages. The sand floods which have buried the works of art on the western countries of the Nile, have contributed greatly to their preservation. Nothing could be better adapted than this dry impalpable dust, to protect the features of the colossal sculptures of the temples, or the paintings upon their walls. Every mark of the chisel remains as perfect as though but yesterday from the sculptor's hand, and the colors of the paintings are as brilliant, as when first laid on, thousands of years ago. At some remote period, when the causes that now make the air move in sweeping winds across the Great Desert towards the Nile shall be removed, when the change of land and sea will perhaps open that desert to the ocean, after the pyramids shall have crumbled, towns and temples of higher antiquity, will be laid open, and a flood of light be shed upon the history of remote ages. Ere that time, the hieroglyphic writing will be thoroughly understood, and the years of the Egyptian dynasties as well determined as the reigns of modern kings. The great agent of decomposition in other places, moisture, is unknown there. The spectator who looks for the first time upon the immense cavern temple at Ipsambul in Nubia, might well imagine that the artists had just left their work. The walls are as white, the colors as perfect, and the outlines as sharp, as in the first hour of their ex-

istence, and when he surveys the tracings, and half-finished sculpture he might almost look for the return of the artists to complete their work. Such is the wonderful preservation of these works in the fine blown sand of the great deserts, that although the buildings have been roofless for two thousand years, the paintings are undefaced. "There are some small chambers in a temple at Abydos" says Sir F. Hennicker, "in which the color of the painting is so well preserved that doubts immediately arise as to the length of time that it has been done. The best works even of the Venetian school, betray their age; but the colors here, which we are told were in existence two thousand years before the time of Titian, are at this moment as fresh as if they had not been laid on an hour." The preservation of works usually esteemed as fugitive, being so perfect, we might expect that those executed in more durable materials the sienite, granite, basalt, and limestone, would be still more so, and we find fragments of temples leveled to the ground by Cambyses, five hundred years before the Christian Era still retaining their pristine polish. The north and east faces of the obelisk, still erect among the ruins of Alexandria, retain much of their original sharpness, but the south and west sides have been entirely defaced by the attrition of the minute particles of sand with which the air is charged, beating against them sixteen hundred years. The desolation brought upon those ancient cities by the irresistable encroachments of the desert, the remains of its immense temples and works of art, its silent chambers, where the wrapped-up dead have remained for two hundred centuries, who once trode the streets of ancient Thebes, with all the buoyancy of feeling and all the hope which animates men now, furnishes a striking instance of the influence of apparently insignificant causes, in producing the greatest results, and remind us of the prophet's declaration, "Wo to the land shadowing with wings." But the ancient cities of Nubia, and Upper Egypt, are not the only places buried in blown sand, there are numerous instances of towns and villages, in England and France, thus overwhelmed. For example, near St. Pol de Leon, in Brittany, a whole village was completely buried beneath drift sand, so that nothing but the

spire of the church could be seen. In the course of a century it is said that a thousand acres of land in Suffolk were covered by blown sand; and a considerable tract of land on the north coast of Cornwall has been thus inundated, and ancient buildings are often brought to light by its shifting; and in some cases, in boring for water, distinct strata of the sand separated by a vegetable crust are found. The name of dunes, or downs, has been given to these moving sand hills, which are first generated on the sea shore. The sea-breeze drives the fine sand, farther and farther inward, until it accumulates and becomes a formidable hill. There are many instances of these hills in the United States, particularly in the south eastern part of Massachusetts, and near Cape Cod, where they are sixty or seventy feet high, and of almost snowy whiteness. Here these dunes are moving gradually westward, the strength of the land-breeze not being sufficient to counteract the effect of the sea-breeze. A series of these dunes now threaten the village and Bay of Provincetown, and large quantities of beach-grass have been transplanted to their ridges for the purpose of arresting their progress.

The chemical agency of the atmosphere is another important means of change producing a sure and often rapid decay of the solid materials of our globe. The forces of chemical affinity are superior to those of cohesion and aggregation, and the atmosphere charged with moisture and carbonic acid gas, disintegrates the solid materials, which crumble away before this "gnawing tooth of time." The resistance which rocks afford to decomposition depends greatly upon their composition, but all are more or less affected. A very slight examination of the soil in any rocky country will suffice to show that it has been derived from the decomposition of the rocks in the vicinity. In granitic countries we find the soil made up of shining particles of silex or quartz, and spangles of mica, and particles of felspar, and even the finest portions will be found thus composed. Sienite and hornblend rock, when decomposed, yield a darker soil, containing much more felspar and less quartz, while slaty rocks give a dark colored tint to the soil, forming beds of tough blue clay, when deposited by water. We have already alluded to the consolida-

tion of loose materials by the infiltration of calcareous matter, or by iron; the destruction of such aggregations is no less remarkable. Thus we find rocks which contain iron pyrites or sulpuret of iron, constantly crumbling to pieces. The oxygen of the atmosphere, and of the watery vapor with which it is charged, combining with the sulphur, forms sulphate of iron or copperas, the sulphuric acid of which, acts powerfully on the rock. Rocks which contain potash and soda are also very liable to disintegration. Indeed, it is not a little remarkable that our supplies of these valuable alkalies, particularly of the potash, are obtained from the vegetable kingdom, salts of potash containing some vegetable acid are of constant occurrence in plants, performing a hidden but yet important part in their economy; when these plants are burned, the organic acids are destroyed, and the potash remains in the state of carbonate, or united with carbonic acid. The great natural depository of potash is the felspar of the granitic and other unstratified rocks, combined with silica in an insoluble state. When these rocks disintegrate into soil, the alkali acquires solubility. Rocks which readily absorb moisture are liable to decay; the red sandstone, or freestone, for example, which is destroyed very rapidly according to its porosity, by the splitting of portions of the stone in consequence of the freezing of the water. De la Beche, observes that, "rocks receive considerable chemical modification by the percolation of water through them. There is scarcely any spring-water, which does not contain some mineral substances in solution, which it must have procured in its passage through the rocks. Now, though this quantity may be small, when we regard the composition of any particular spring-water, yet, when we consider the soluble matter contained in the spring-waters of any given 1000 square miles of country, and that this subtraction of matter from rocks has been going on for ages, we may readily conceive that the chemical change, may be greater than, at first sight we might anticipate. We may also infer that the most soluble portions of rock, have a constant tendency to be removed, when exposed not only to direct atmospheric influences, but also to the percolation of rain-water through them, so that most rocks would experience

great difficulty in resisting chemical changes of this kind, and of preserving their original chemical nature, more particularly when elevated into the atmosphere." We have already had occasion to remark upon the large amount of calcareous and silicious matters held in solution by water, which matter has been often derived from the percolation of that fluid through limestone districts, or rocks containing felspar, for it is well known that in the decomposition of such rocks, producing the porcelain clay, an enormous quantity of silex is carried off in solution. In the region of extinct volcanoes in France, the district of Auvergne, the destruction of granite is very rapid, owing to the liberation of large quantities of carbonic acid. "The disintegration of granite," says Lyell, "is a striking feature of large districts in Auvergne. This decay was called by Dolomieu 'la maladie du granite,' and the rock may, with propriety, be said to have *the rot*, for it crumbles to pieces in the hand. The phenomenon may, without doubt, be ascribed to the continual disengagement of carbonic acid gas from numerous fissures. In the Plains of the Po, I observed great beds of alluvium, consisting of primary pebbles, percolated by spring water, charged with carbonate of lime and carbonic acid in great abundance. They are, for the most part, incrusted with calc sinter; and the rounded blocks of gneiss, which have all the outward appearance of solidity, have been so disintegrated by the carbonic acid as readily to fall to pieces."

We can now perceive how little of stability or permanancy is inscribed upon the face of nature. The gilded insect which flutters its short hour over the flowers of a day, deems its life and happiness lasting, and what better are our own thoughts; we look upon the earth as unchangeable, when, for ought we know, the next instant may behold all our possessions swallowed up, or blown into the air. We carve to ourselves costly monuments, perpetuating the deeds of martial bravery, or the fame of a patriot, we protect them from the hands of the rude by various means, but a more formidable enemy, because less known, and dreaded, is passing by, and silently effecting the work of desolation. Change, perpetual change, is inscribed by the finger of the Almighty upon the face of everything. No art can arrest the insidious at-

tacks which thus cause the richest works of man to crumble silently away.

"It is painful," says Philips, "to mark the injuries effected by a few centuries on the richly sculptured arches of the Romans, the graceful mouldings of the early English architects, and the rich foliage of the decorated and later Gothic styles. The changing temperature and moisture of the air communicated to the slowly conducting stone, especially on the western and southern fronts of buildings, bursts the parts near the surface into powder, or, by introducing a new arrangement of the particles, separates the external from the internal parts, and causes the exfoliation or desquamation, as Mac Culloch calls it, of whole sheets of stone parallel to the ornamental work of the mason. From these attacks no shelter can wholly protect; the parts of a building which are below a ledge often decay the first; oiling and painting will only retard the destruction; and stones which resist all watery agency, and refuse to burst with changes of temperature, are secretly eaten away by the chemical forces of carbonic acid and other atmospheric influences. What is thought to be more durable than granite? Yet this rock is rapidly consumed by the decomposition of its felspar, effected by carbonic acid gas; a process which is sometimes conspicuous even in Britain, but is usually performed in Auvergne, where carbonic acid gas issues plentifully from the volcanic regions."

The most durable rocks appear to be the limestones of the Silurian formation, but some of the sandstones of the more recent formations are exceedingly perishable. This may be seen upon examining the tombstones of red sandstone, which were formerly used very extensively in New England, their inscriptions will generally be found illegible. The durability of sandstones depends much upon the nature of the cement which binds the particles together, if this be calcareous they are not so durable as if silicious, and if the stones contain iron, they are generally highly perishable. Such stones which, may always be detected from their iron-brown, or rusty appearance, should be rejected for building stone.

Such are some of the effects of causes continually, and yet silently operating around us. It is true that many years are required to produce changes of great importance, and the operation is so gradual that the wonder ceases, almost ere it begins. In investigations however, so comprehensive as those we have been considering, a day, a year, or a hundred years, is but as the grain of sand to a mountain. It is indeed very true that the present generation may pass away, and yet think they leave all things as they were of old, looking with a listless apathy upon the face of nature. The true philosopher improves the fleeing moment, and enlarges his affections, and expands his imagination by the contemplation of loftier subjects, and so fits himself to depart from this changing scene, with the consolation of not having lived in vain.

CHAPTER X.

Coral Animalcules.

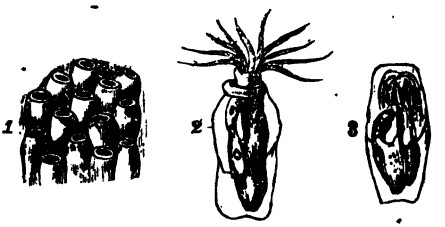
"Deep in the wave is a coral grove,
Where the purple mullet and gold-fish rove,
Where the sea-flower spreads its leaves of blue,
That never are wet with falling dew,
But in bright and changeful beauty shine,
Far down in the green and glassy brine."

Percival.

We now enter upon a most interesting branch of our subject, the influence of organic action in producing change, and we will soon find that of all agents which at the present moment are forming rocks, the most remarkable are those minute and fragile animals termed Coral Animalcules. A vast number of islands in the Pacific, Indian, and Atlantic oceans are entirely composed of the calcareous skeletons of these minute animals, and they are at the present moment rapidly increasing in their extent. Straits and seas, once easily and safely navigable, are now rendered extremely dangerous, and even impassable. It will not be unprofitable or uninteresting to devote a short space to the consideration of these wonderful specimens of organic existence.

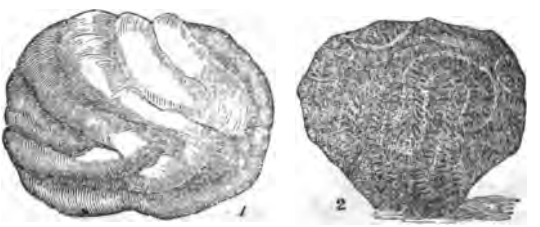
The nature of coral animalcules is but little understood by most persons, they suppose that the hard calcareous substance called coral, is a part of the animal itself, this, however, is not the case. The stony substance, may be compared to an internal skeleton, for it is surrounded by a soft animal investment, capable of expanding, and when alarmed, of contracting and drawing itself almost wholly into the hollows of the hard coral. Though often beautifully colored in their own element, yet when taken out of the water they appear like a brown slime spread over the stony nucleus. The coral animalcules exist in a great variety of forms

and of various sizes, some of them are so minute that they cannot be seen without a microscope. They are congregated together like other zoophytes, each individual being connected to a common body, so that what is received by any one goes to the nourishment of the whole. The stony matter, or hard substance of the zoophyte, is formed as are the bones and nails in man, by secretions from the animal substance, by which they are penetrated and invested. The cells of the coral, therefore are not built up by the polypi, as they are called, in the same manner as the waxen cells of the bee. We may often observe little patches of yellowish calcareous matter on sea-weed, or shells thrown upon the shore, this upon examination appears to be a kind of delicate net-work, but when examined with a microscope the substance is found to be full of pores, and if the examination is made while the *flustra* or calcareous matter is immersed in the water, each pore will appear to be the opening of a cell, whence issues a tube with several long arms or feelers; sometimes these expand, and then suddenly close and are withdrawn into the cells, then issue forth again. Thus each individual of the group occupies its own particular cell, but the whole constitutes one family of polypes connected by a common integument, or fleshy or gelatinous substance which invests the whole. Figure 1, of the wood-cut below exhibits the series of cells of the flustra, systematically



arranged. Each cavity is the receptacle of a polype shown with the tenlacula, or feelers, expanded in fig. 2, and contracted into its cell in fig. 3. These views are from drawings made by Mr. Lister, and figured by Dr. Mantell, in his excellent "Wonders of Geology." The animals just described are members of the same

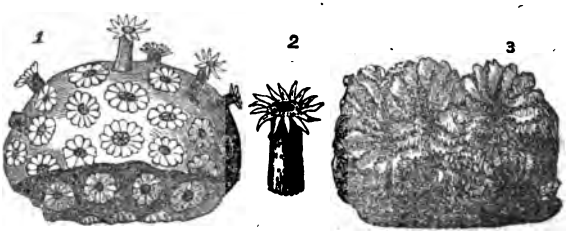
family by whose secretions vast reefs of coral rocks are formed, and mountain masses of calcareous matter produced. They belong to the order *Coraliferi*, or coral-making, and the class *Polypi* of Cuvier's Animal Kingdom. The mode of increase of the polyparia is very remarkable. If the flustra just referred to, be carefully watched, a small globule will be observed to be thrown off from the mass, and attaching itself to the sea-weed or rocks, will become the germ of a new colony of this compound animal, as it increases in size it will exhibit upon closer inspection the usual characteristics of the flustra, and if the gelatinous or jelly-like substance is removed, a small spot of calcareous matter will be found. The stony secretions of the coral forming animals, appears upon examination to be of the same character as that of shells; some specimens appearing of the same composition as the pearly shells, and others the same as the enamelled shells. In form and color there is condiderable diversity. Our limits will only permit us to give figures of several of the different species, without a lengthened or minute description. The most common varieties of corals, which compose the coral reefs and banks, are the following, according to Lamarck. The Meandrina, or brain-stone coral, which derives its name from the meandering cells, and its general appearance, which resembles the brain, as figured below. Figure 1, represents the animal as seen alive in the sea,



the polypi are retracted or concealed, it is of a reddish or fawn color. Fig. 2 is the coral as it appears when divested of its gelatinous covering. This zoophyte sometimes attains the size of four feet in circumference. The base of the Meandrina is firmly attached to the rocks with which it soon becomes identical: as each

successive fleshy mass expires, a new one appears, which gradually expands and deposits its calcareous secretions upon the old one, and thus vast beds of stony matter are accumulated in the bottom of the sea, and become the foundations of coral reefs and islands. "We may compare" observes Mr. Lyell, "the operation of these zoophytes in the ocean to the effects produced on a smaller scale upon the land by the plants which generate peat. In the case of the *Spagnum*, (page 204), the upper part vegetates while the lower portion is entering into a mineral mass, in which the traces of organization remain, when life has entirely ceased. In corals, in like manner, the more durable materials of the generation that has passed away, serve as the foundation on which living animals are continuing to rear a similar structure." The Caryophilla, or branched star-like coral, is another common species. We give an engraving of an American specimen as it appears when alive. The three branches, each

contain a bright green polypus. The Astrea, is another very common and extensive species of coral, fig. 1, represents the



coral as seen alive in the sea, the polypi are of a dark green

color, and about half an inch in length, protected by deep laminated polygonal cells one-sixth of an inch wide; fig. 3, represents the coral with the animal removed, its name astrea or star-like, is derived from its radiated or starry appearance. Fig. 2, is a magnified view of one of the polypes. The tentaculae, or arms, are seen arranged around the mouth. The appearance of these animals alive, and in activity, is most beautiful when viewed in tranquil water. The surface of the rock appears like a living mass, presenting a great diversity of appearance and color. The Madrepore, or branched cellular coral, is well known, being perhaps the most common species. It will be immediately recognized upon inspecting the figure we have given below. In some

species after the fleshy investment perishes, the little cells appear very numerous as in the figure. The white branched corals usually seen in collections belong to this genus. In the water, the Madrepores are invested with fleshy integuments of various colors and each cell is furnished with its own polype. We have now enumerated the several species of zoophytes most active in the formations of reefs. The stony secretions of all these, when bleached by the action of moisture and light, are of a dazzling whiteness. There is however, a species of coral, *Corallium rubrum*, or red coral, the stony secretion of which is a bright red color, very beautiful and susceptible of a high polish. A specimen of this coral is here figured. It consists of a brilliant red stony axis invested with a fleshy or gelatinous substance of a pale

blue color, attached to the rocks by a broad expansion of its base.

In the figure, the fleshy substance is removed at the extremities to exhibit the stony axis. It is seldom found more than a foot in length, and is well known, being used for various ornamental purposes, and is obtained by dredging in various parts of the Mediterranean and Eastern seas. Another species of red coral,

the organ-pipe, or *tubipora*, is shewn in the above wood-cut, this derives its name from its tubular appearance, being composed of parallel tubes united by lateral plates or transverse partitions placed at regular distances. The polypi of this coral are of a beautiful green color. This species occurs on the coast of New South Wales, and in the islands of the Molucca group, in hemispherical masses of from one to two feet in circumference, which first appear as small specks, adhering to the rock, these gradually increase, and the tubes shoot forth like little rays; other tubes spring from the transverse plates, finally constituting a uniform tubular mass, the surface being covered with a green fleshy substance, beset with stellar animalcules.

The geographical distribution of corals is very extended. The Pacific, throughout a space comprehended between the 30th parallel of latitude on each side of the equator is very productive, and also the Persian and Arabian Gulfs. They are very abundant

in the Indian ocean and some parts of the Atlantic. Many species of this genus are found along our Atlantic coast and on the shores of England. Some species seem to prefer the more exposed situations, flourishing in the greatest profusion, on rocks and plants which the tide every day leaves bare; the larger polyparia however, are seldom found in places exposed to violent currents; they flourish in the submarine grottoes and hollows of the rock, where they shoot out their delicately branching forms studded with zoophytes of most brilliant colors. Others attach themselves to the flexible branches of the sea plants, encasing them in a living tomb, and are thus fitted to enjoy the powerful action of the surges; the pliant branches bending to and fro, with the movements of the waters. Others form immoveable rocks, and slowly increase, until at last an island is elevated above the waters. The distribution of corals, like that of plants, varies with the climate. In the colder northern latitudes, a few sponges, and sertulariæ alone are found, but in the warmer, equatorial regions, within the tropics, they attain a luxuriance and beauty, a grandeur and importance well worthy our attention. Here, in an ocean of uniform temperature, they elevate those immense reefs which eventually become the habitations of men, and even gardens producing rich tropical fruits and flowers. These minute beings, myriads upon myriads, here exercise their empire, sometimes, in the sheltered places, or still lagoons, shooting forth the most delicate branches, and in others, where the surges beat upon them, growing firm and solid as the rock on which they are based. The appearance of the living corals in the water is described as most enchanting. The whole bed of the Red Sea is absolutely a forest of sea-plants and corals, presenting the appearance of a submarine garden of the most exquisite verdure, resembling in splendor and gorgeous coloring the most celebrated parterres of the East. Ehrenberg, the distinguished German naturalist, so well known by his admirable investigations of infusoriæ, was so struck with the view of the living corals in the Red Sea, that he exclaimed with enthusiasm "Where is the paradise of flowers that can rival in beauty these living wonders of the ocean?" Some

have compared their appearance to beds of tulips or dahlias; and, in truth, the large fungiæ, with their crimson disks, and purple and yellow tentacula, bear no slight resemblance to the latter.

The tender branches of the corals furnish food to some species of fish, which graze upon them in whole shoals, both within the lagoons in the quiet waters, and among the breakers on the outside of the reef. Nothing can be imagined more beautiful than the scene presented in the tropical climates, especially where the shore consists of alternate beds of sand, and masses of rock. "Groves of coral are seen expanding their variously colored clumps, some rigid and immovable, and others waving gracefully their flexile branches; shells of every form and hue, glide slowly among the stones, or cling to the coral boughs like fruit; crabs and other marine animals, pursue their prey in the crannies of the rock, and sea-plants spread their limber fronds, in gay and guady irregularity, while the most beautiful fishes are on every side sporting around."

CHAPTER XI.

Coral Islands.

"I saw the living pile ascend,
The mausoleum of its architects,
Still dying upwards as their labors closed;
Slime the materials, but the slime was turned
To adamant by their petrific touch."

J. Montgomery.

HAVING in the preceding chapter given a brief description of some of the more common varieties of corals, we shall now consider more fully the agency of these wonderful animals in the formation of rocks. It has been generally considered that the zoophytes cannot live in water of very great depths, and that therefore their structures are based upon submarine mountains. This view has been confirmed by the observations of Ehrenberg, and more recently by the careful soundings of Captain Fitz Roy, of the Royal English Navy. At a depth of ten fathoms the prepared tallow invariably came up marked with the impressions of the living corals, and as clean as if it had been dropped on a carpet of turf; at a greater depth the impressions were less numerous, and the adhering particles of sand much more frequent, until at a mean depth of twenty-five fathoms it was evident that the bottom consisted of a smooth sandy layer. We may conclude therefore that the reef building corals, do not usually flourish much below this depth. The formation of the coral islets is somewhat analagous to the growth of a tree which has been headed. The zoophyte cannot endure even a short exposure to the sun's rays in the air, their growth upwards is therefore checked as soon as the surface of the water is reached. They spread out laterally however, not unlike the top of a tree.

The appearance and formation of coral islands has been described very minutely by a great number of distinguished naturil-

ists, and various theories have been proposed to explain the observed phenomena. We have devoted some little attention to this part of our subject, and are best satisfied with the explanation given by Mr. Chas. Darwin, in a paper read before the Geological Society in May 1837, and which we will explain presently. Everywhere in the Pacific and Indian Oceans, within the tropics, may be seen coral banks in their various stages of progress; some covered with light soil, and the habitations of man. Most of the reefs which raise themselves above the waters are of a circular form, enclosing a basin of still water, called a lagoon, which connects by means of one or two channels with the sea. In the interior of the island, the more delicate and smaller kinds of zoophytes live, while the stronger and hardier species, fitted to endure the beating of the surf, flourish on the outer margin of the isle. When the reef rises so high that it is left uncovered at low water, the corals cease to increase, the animals die, and the branches become somewhat decomposed. Fragments of coral limestone are thrown up by the waves, with shells, and broken fragments of crustacean animals, seeds are floated by the waves towards the new formed island, and thrown upon its shores; and trunks of trees, drifted thousands of miles, find a lodgment upon it, bringing with them small animals, as insects and lizards. Bushes and trees, spring up, and the sea-birds nestle there, and finally at a later period, it becomes the habitation of man. The reefs of coral, consist not only of the corals, and their broken fragments, but masses of compact limestone, and imbedded shells are of frequent occurrence. The limestone is found sometimes in the uppermost or newest parts of the reef, and is formed by chemical decomposition, the carbonate of lime being supplied from the decomposition of corals and testacea.

We have already alluded to the geographical distribution of corals, we may however, form some idea of the immense extent of the coral reefs when we learn that, off the coast of Malabar, in the Indian Ocean, there is a chain of coral islands of over 480 miles in length, called the Maldiva Group. On the coast of New Holland, is an unbroken reef 350 miles in length, and between that and the island of New Guinea is a coral formation which

extends upwards of 700 miles; and Disappointment Island and Duff's Group, are connected by a coral reef of 600 miles length, over which the natives pass from one island to another.

Coral reefs are divided into three great classes, namely Atolls, Barrier, and Fringing reefs. The word atoll is the name given by the natives to the circular islands enclosing a lagoon, or still water in the centre. This is the most usual form of the coral islands, and fails not to strike the attention of every one who has crossed the Pacific. They occur of all sizes; of thirty-two examined by Capt. Beechy, the largest was thirty miles in diameter, and the smallest less than a mile, they were of various shapes and all but one, formed by living corals. This one had been raised from the water about eighty feet, but was of coral formation, and was encircled by a reef of living corals. All were slowly increasing their size, and twenty-nine of them had lagoons in the centre, which had probably existed in the others, until, in the course of time, they were filled by the labors of the zoophytes, and other substances. It was supposed by the earlier voyagers that the coral-building animals instinctively built in the form of great circles to protect themselves from the fury of the waters. So far however, from this being the case, we have seen that those massive kinds upon whose existence and increase, the reef depends, flourish best among the breakers on the outside of the reef. Another and more probable theory, is that advocated by Mr. Lyell, that they are based upon the crests of submarine craters, and this idea receives confirmation from the steep angle at which the island plunges at all sides into the surrounding ocean, and that every island yet examined in the immense region called Eastern Oceanica, consists of volcanic rocks, or coral limestones. In opposition to this opinion it is very plausibly argued by Mr. Darwin, that the form and size of some, and the number, proximity, and relative positions of others, are incompatible with this theory. Thus, Suadiva atoll is 44 geographical miles in diameter in one direction, and 34 in another; Rumsky atoll is 54 by 20 miles across; Bow atoll is 30 miles long, but only six in width. Another theory, proposed by Chamisso, accounts for the circular form of coral islands upon the well known fact, that the corals

growing more vigorously around the outside where exposed to the sea, the outer edges would grow up from the foundation before any other part; thus making a ring or cup-shaped structure; but we are not by this theory relieved from the difficulty of answering the question, upon what are these massive structures based? since it is well known that the reef-building corals cannot live at any very considerable depth, though indeed, other species have been found at a depth of 60 fathoms. Below we give a view of one of these islands, copied from Capt. Beechy. The circular form is well exhibited in this island, which is called Whitsunday, but it gives a faint idea of the singular appearance of an atoll,

being one of the smallest size. The immensity of the ocean, the fury of the breakers, contrasted with the lowness of the land, and the smothness of the bright green water within the lagoon can hardly be imagined without having been seen.

The second great class of reefs are the Barrier-reefs, these are similar in all respects to the atolls except having a high land like a castle rising out of the lagoon. The following sketch from Mr. Darwin, will give an idea of the appearance of one of these wonderful structures, being a part of the island of Bolabola in the Pacific, as seen from one of the central peaks. In this instance the whole line of reef has been converted into land, upon which trees are growing; but generally, a snow-white line of breakers, with only here and there a low islet covered with cocoa-

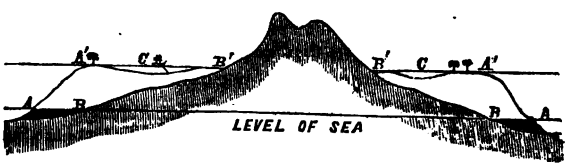
nut trees, can be seen separating the dark heaving waters of the ocean from the light green expanse of the lagoon, the still waters

of which, within the reef, usually bathe a fringe of low alluvial soil, upon which the varied and beautiful productions of the tropical regions flourish at the foot of the abrupt and wild central peaks. In the sketch given above, the barrier-reef may be seen in the distance skirting around the island. These reefs are of all sizes from three to forty miles in diameter; and the one which encircles both ends and fronts one side of New Caledonia is upwards of 400 miles long. Externally the reef rises like an atoll with abruptness out of the profound depth of the ocean, but internally it either slopes gradually into the channel, or terminates in a perpendicular wall 200 or 300 feet in height.

There is one remarkable feature connected with the circular reefs, and that is, a deep and narrow passage almost invariably opening from the sea into the lagoon, and kept open by the efflux of the sea at low tides, and it has long been remarked in the case of the barrier reefs, that this channel or opening alway faced valleys in the included land.

The third great class are the Fringing reefs, these, so far as the coral reef itself is concerned, do not differ materially from the others, except that the encircling belt of coral is much narrower. Where the land slopes abruptly into the water the reefs are but a few yards in width, forming a mere ribband or fringe around the island, but when the slope is gradual, the width is much increased

extending sometimes as far as a mile from the land, and always to such a distance from the shore that the limiting depth of 20 or 30 fathoms is obtained, where the reef ceases. From the more flourishing growth of the outermost corals, the fringing reefs are usually highest at the outside, and the sediment washed inwards upon the reef, generally produces in the course of time, a shallow sandy channel. Such are the three great classes of coral reefs which are found scattered throughout the vast oceans, and principally in the tropical regions, but it must by no means be supposed that they are found indiscriminately united, on the contrary the atolls and barrier-reefs are never found in proximity to the fringing reefs. It has been remarked with surprise that while atolls are the most common coral structures throughout some vast portions of the ocean, such as the tropical Pacific and the Indian Oceans, they are entirely wanting, or very nearly so, in the tropical Atlantic and West Indian Seas, where the corals themselves, are exceedingly numerous. There is also another somewhat remarkable fact, that no single active volcano occurs within several hundred miles of a coral archipelago, or even a small group of atolls; and although most of the islands in the Pacific which are encircled by barrier-reefs are of volcanic origin, having remains of craters distinctly visible, yet not one of them is known to have been in eruption since the growth of the corals. In explaining by any theory the formation of coral reefs, we must consider all the phenomena presented by the three great classes as enumerated in the preceding description. To ourselves the explanation proposed by Mr. Darwin in his volume upon "The structure and distribution of Coral Reefs," is the most satisfactory, and may be briefly stated thus; islands, or a line of coast, being first skirted with fringing reefs, become atolls by a continual but gradual subsi-



dence of the land. Let us then take an island surrounded by

fringing reefs, and let this island with its reef, represented by the unbroken lines in the wood cut, slowly subside. As the island sinks down, the reef continually grows upward; as the island subsides the space between the inner edge of the reef and the beach becomes proportionally broader. A section of the reef and island in this state is represented by the dotted lines, A A, being the outer edges of the reef; C C, the lagoon; B B, the shores of the encircled island. This section is a real one (on the scale of .388 of an inch to the mile), through Bolabola in the Pacific. We can now see why the barrier reefs are so far from the shores which they front. Supposing the island to still subside, the corals meantime growing vigorously upward, the last traces of land will finally disappear, and a perfect atoll be formed. We thus perceive why atolls so much resemble the barrier reefs in general size, form, and manner in which they are grouped together, for they are but the rude outlines of the sunken islands over which they stand. In proof of the foregoing simple and not at all improbable cause for the formation of barrier reefs, and atolls, Mr. Darwin gives some examples of actual subsidence now in progress, and also presents some evidence of the recent elevation of those islands and coasts which have fringing reefs. The sinking of the islands, or coast, for the formation of barrier reefs, or atolls, must necessarily have been very slow, and undoubtedly large archipelagos and lofty islands once existed, where now only rings of coral rock scarce break the open expanse of the sea; thus the only record left to us of the existence of vast tracts of land are the wonderful memorials of these busy architects; in each barrier reef we see evidence of land subsided, and in each atoll a monument of an island lost. Busy from the first ages of the world, when the primeval seas had but a few groups of living beings, of the lowest order of organization, the coral polype has toiled from day to day, and year to year, and is toiling now. What mighty changes have passed over our globe since that remote period in which the Geologist is first enabled to trace the existence of living beings upon the earth. How many tens of thousands of times the earth has revolved around the sun, and how many huge mountain chains of granite have been disintegrated, and their scattered frag-

ments deposited in the deep bed of the ocean. Perhaps the foundation of some of our present coral islands, was begun in those remote ages, and that the successive architects of the solid pile, have reared a structure which has witnessed more than one revolution of the major axis of the earth's orbit.

We close with the following beautiful description of a coral grove, by Percival.

"The floor is of sand, like the mountain-drift,
And the pearl-shells spangle the flinty snow;
From coral rocks the sea-plants lift
Their boughs, where the tides and billows flow;
The water is calm and still below,
For the winds and the waves are absent there;
And the sands are bright as the stars that glow
In the motionless fields of the upper air.
There with its waving blade of green,
The sea-flag streams through the silent water,
And the crimson leaf of the dulse is seen
To blush like a banner bathed in slaughter;
There with a light and easy motion
The fan-coral sweeps through the clear deep sea;
And the yellow and scarlet tufts of ocean
Are bending like corn on the upland lea;
And life in rare and beautiful forms
Is sporting amid those bowers of stone,
And is safe when the wrathful spirit of storms
Has made the top of the waves his own.
And when the ship from his fury flies
Where the myriad voices of ocean roar,
When the wind-god frowns in the murky skies,
And demons are waiting the wreck on shore,
Then far below in the peaceful sea
The purple mullet and gold-fish rove,
Where the waters murmur tranquilly
Through the bending twigs of the coral-grove."

CHAPTER XII.

Organic Remains.

"And thou didst shine, thou rolling moon, upon
All this, and cast a wide and tender light,
Which softened down the hoar austerity
Of rugged desolation, and fill'd up,
As 'twere, anew, the gaps of centuries."

Byron.

In the preceding chapters we have, though somewhat imperfectly, given a sketch of the great causes of change now in operation on our globe, and we have shown that the earth's surface has been, and still is, subject to perpetual mutations. What was once dry land is now the bed of the ocean, and what is now the bed of the sea will one day be elevated land. We have also seen that the crust or superficial covering of the globe is composed of strata succeeding each other in a well determined and regular order, and the remains of countless myriads of animals are entombed in them, which lived and died at periods long antecedent to the creation of the human race, nay, more than this, that almost every grain of sand and particle of dust wafted by the wind, teems with organized matter. We have lying before us specimens of whitish earth which to the unassisted eye appears but light chalky powder; we have but to wet a little of it and place it under the microscope and a thousand perfect forms are visible. From the midst of a lump of chalk we have extracted a nodule of flint, and by the hammer have chipped off several thin slices; one of these is now under the microscope by us, and we distinctly recognize two beautiful species of infusoria, as perfect and well defined as though now alive, and yet, these little beings have been entombed for myriads of years. What mighty changes have come over the face of our globe since the flinty sea encom-

passed them, and how few of the countless thousands of all that sea, have been preserved for the curious gaze of the student of nature. The thoughts which overwhelm the mind when contemplating the wonders of the universe, impress us with almost a feeling of sadness that creation is so vast we can never comprehend the whole of it. The influence however, of scientific pursuits upon the mind, is most beneficial, and the great lesson taught by science is, that our habitual ideas, and our first impressions are far from being nearest the truth. Indeed we have already observed in the first part of this work, that Astronomy begins by convincing us that the sun, which apparently is revolving around the earth, is in reality still, but that our globe is turning daily on its axis, although apparently unmoving. Geology in like manner begins with even more unpleasant truths, and convinces us that the present configuration of the continents and seas, so far from being the primeval condition of things, is but one of the various vicissitudes through which the world has passed.

We are accustomed to consider the earth as coeval with man, and that but five or six thousand years have elapsed since their creation. Geology demonstrates that our present abode is of far greater antiquity, and the slightest examination of the crust of the earth will convince us, that the substances of which it is composed, are the results of accumulations or deposits extended through a long period of cycles. As we have already observed all the strata, with the exceptions of the igneous rocks, the granite, the gneiss, and the mica-schist systems, are fossiliferous, and it is highly probable that even these rocks are of sedimentary origin, and once contained the remains of organic matter. The vast series of other deposits are the undoubted mineralized beds of primeval oceans, with occasional interpositions of lacrustine or lake formed, and fluviatile or river deposits, the former rivaling those of the vast Atlantic and Pacific, and the latter those of the immense inland lakes and rivers of the American continent. We do not find these mineralized beds or rocks, in all cases bearing the marks of quiet, but showing the agency of numerous disturbing influences, they have been upheaved and bent over; and broken through by the erupted and molten masses from beneath,

which have flown up through wide chasms and overspread them. Intervals of unusual volcanic agency, have been succeeded by ages of tranquil repose, and these again succeeded by a revival of former energy. We see in all these vast changes the controling power of an Eternal Mind; periods of time which man in vain endeavors to comprehend, have witnessed continual exhibitions of creative power and wisdom. The diversified materials of which the earth is composed, have been elaborated into beauty and order, every object has its sphere of usefulness and action, and its period of existence is limited. We have never been able to perceive at all the grounds for the too hasty conclusion which some superficial philosophers have adopted, that the present perfect system of organization is the result of a progressive development of inferior types of existence, and that the remote origin of all life is the monad or animalcule.

It has ever been the attempt of man to penetrate beyond the ordinary boundaries, which nevertheless, like the almost impassible barriers of a deep ocean surround him. Now with his heaven-directed tube, he speculates upon the former conditions of all worlds. Penetrating back to periods of time far beyond the dream of the geologists, he imagines the wisps of nebulous matter which in a clear night, with the most powerful glasses, he can just descry, and which appear as rare and light as the thinnest vapor which floats in the form of a cloud on a summer's eve, these he imagines slowly condensing, and gradually forming worlds. The geologist looks back to the remote and primeval ages when the first life appeared on our planet, and he uncovers with careful hand the imbedded remains of fragile plants, and shells, which have lain hidden in their stony beds for periods of time compared with which, our years dwindle to utter insignificance.

The whole substance of our globe, at least so far as the solid materials which compose its crust are concerned, may be divided into two great classes, minerals and fossils.

MINERALS are inorganic substances, and are the products of chemical or electrical action.

FOSSILS are the remains of organic substances imbedded in the strata by natural causes at some remote period, and these remains

are of the utmost importance in the eyes of geologists. If we examine the successive beds of water deposits in the various parts of our country we soon find that peculiar and characteristic fossils belonging to one locality. Or if we penetrate the earth to such a depth that we reach the strata, which at some distant place may crop out, or appear on the surface, as explained page 184, we will then find the same fossil remains as would be found at the surface at that distant place. The inference which we naturally draw from this is, that if at different ages of the globe, when the successive strata were deposited, different races of animals and vegetables flourished, then these fossil remains will enable us to determine with something like certainty, the relative ages of the strata which compose the various parts of a country, for it must be remembered that the mineralogical character of most of these beds is the same, and many times no opinion whatever can be formed from this. Hence these remains have been appropriately termed the "Medals of Creation," and they afford to the geologist precisely the same evidence of the character of the period when they existed, and were deposited, as an ancient coin to the numismatist, of the character of the people, and the period when it was struck. Oftentimes a single coin or medal, is the sole remembrance which exists, to determine the date of a great event, and so a few bones, a shell, or a tooth, or track of a bird in the sand, are the sole memorials of peculiar types of existence of the primeval world. It would seem at first that from the very nature of the materials which compose most organic substances, that all traces of them would soon be obliterated. It is true that the soft and delicate parts of animal and vegetable organisms rapidly decay after death, yet in certain cases, their decomposition is arrested, and by a peculiar process every part is transformed into stone; thus, many of the most perishable vegetable tissues have been preserved, and even in the anthracite coal, which has been burned in the grate, distinct traces of organic structure can be observed under the microscope. The woody fibre of vegetables, the bones and teeth of animals, deeply imbedded in the earth, are thus preserved in some instances with wonderful accuracy and perfection. The perishable fleshy parts

of the animal of the Belemnite, a characteristic fossil of the Oolitic group, have been thus preserved in indurated clays, and of the cuttle-fish in limestones. The delicate impressions of plants of the various epochs stamped in the sandstones, shales, coals, and chalks, are presented with the utmost fidelity. The silicious shells of animalcules are everywhere abundant; in our own country whole districts are composed of them; in Virginia, New Jersey, New York, Massachusetts, Michigan, and Iowa, and probably every state of the Union, their remains are more or less common. In a previous chapter we have admired the constructions of the coral-animal, and considered with a feeling of astonishment and wonder, the immense importance of the labors of so apparently helpless and insignificant a being; but what shall we say to the beds of rocks, composed of the remains of animalcules invisible to the eye? yet of such are the pyramids built! Not only are the carapaces, or shelly coverings, of these minute animals preserved, but in many instances the fleshy parts of certain minute chambered shells are admirably preserved, imbedded in the heart of a flint nodule, and one familiar with such appearances, can in the merest fragment of flint, detect various organic bodies. The variety of limestone called encrinital marble, is composed almost wholly of a peculiar stony animal called the Encrinite, and particularly abundant in the carboniferous, or mountain limestone, of the carboniferous group. A specimen from the Helderbergh Mountains near Albany, lies before us, compact and firm as though originally composed of crystaline materials. The ordinary observer can form but little idea of the amount of organic remains distributed throughout the various strata.

In the following chapters we shall consider in order the three great epochs, or periods of the earth's existence as demonstrated from the study of fossil animal and vegetable remains. The first epoch commences with the granitic period, or period antecedent to the introduction of life, and ends with the carboniferous or great coal formation. The second period commences with the new red sandstone, and ends with the cretaceous or chalk system. The third and last period embraces what are termed the tertiary

deposits. We would refer the reader to the chart on page 194, where these divisions will appear marked according to Dr. Buckland, under the names primary, transition and secondary, and tertiary. It will only be possible to give a very superficial sketch of the probable condition of our planet during these several epochs, but we shall endeavor to convey a clear idea of the succession of animal and vegetable life which so strongly characterizes them, so that the reader will be prepared to enter upon a more extended investigation.

It is almost impossible even when writing upon ordinary topics, to avoid the use of technical terms, and perhaps least of all can this use be avoided, when natural history becomes the subject. There is nothing of so much benefit, both in economising the time of the student, and in assisting his memory, as a correct and intelligible system. A well selected name; expressive of peculiar characters, or habits, or localities, conveys a multitude of ideas to the mind, which a common or vulgar name would entirely fail to do, for this reason we shall use the names generally applied by geologists to the several fossils, giving in all cases, their meaning or translation, whenever these words are derived either from the Greek or Latin. The word fossil, which we have often used, meant originally, what was dug out of the earth, it is now however applied only to the remains of organic matter.

The fossil animal kingdom may be divided into six sections.

I. INFUSORIA, or *Animalcules*. The name infusoria is derived from the presence of many genera, or groups of species, in vegetable infusions, not easily observable without the microscope.

II. ZOOPHYTES, or *Animal Vegetables*, a term applied to corals and other animals supposed to resemble plants; the subdivisions of this group are,

1. AMORPHOZOA, or animals of *no regular shape* like sponges and
2. POLYPARIA, or *many producing animals* as the corals.

III. ECHINODERMA, or *spiny skinned animals*, subdivided into,

1. CRINOIDEA, or *Encrinital*, i. e. *lily or cup-shaped animals*.
2. ASTERIA, or *star-formed*, like the star-fish.
3. ECHINIDA, or *spiny* animals, like the sea-urchin, or sea-egg.

IV. MOLLUSCA, or *soft bodied* animals, destitute of bones, under this head are embraced the fossil shells.

1. BIVALVES, or consisting of *two pieces* like the oyster and clam.
2. UNIVALVES, or consisting of *one shell* like the snail and periwinkle; these latter are the true molluscs, and are of a higher degree of organization than the former, possessing a head and eyes, of which the former are destitute.
3. CHAMBERED shells like the nautilus, including both the *testaceous* or *shell covered* genera, and naked molluscs as the cuttle-fish.
4. CIRRIPEDIA, or *hairy-footed* animals, like the barnacle.

V. ARTICULATA, or *jointed* animals, comprising,

1. ANNELATA, or *ringed* animals, like the red blooded worm.
2. INSECTA, or *insects*, i. e. having the body nearly divided in two, like the wasp and fly.
3. ARACHNIDA, or *spiders*.
4. CRUSTACEA, having a *crustaceous skin* like crabs and lobsters.

VI. VERTEBRATA, or animals having a *spinal column* or backbone, subdivided into,

1. PISCES, or *fishes*.
2. REPTILIA, or *reptiles*.
3. AVES, or *birds*.
4. MAMMALIA, or *animals giving suck*.

The animal kingdom is divided into the above great classes, and these are subdivided into a vast number of species, each being characterized by some peculiar and distinguishing mark. The expert anatomist can often from the mere inspection of a tooth, or a claw, determine the character and habits of an animal. Oftentimes this, or even a foot-print in the sand, is all that remains of some now extinct creature, yet by analogy, instituting a rigid and close comparison with existing species of the same genera, the peculiarities are distinctly made out, and many remarkable facts are brought to light. We now proceed to consider the probable condition of our planet during the stages of existence before enumerated.

CHAPTER XIII.

The first Epoch.

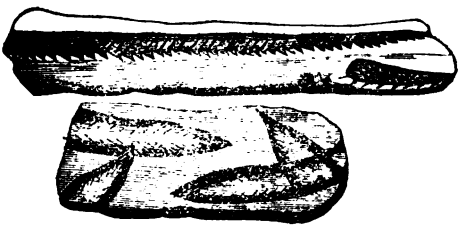
"The land that hath no summer flowers,
Where never living creature stood;
The wild, dim, polar solitude:
How different from this land of ours!"
Mary Howitt.

THE first great period, commences with the granitic and ends with the coal formation. Beneath the most ancient deposits lies a crystaline rock which, under the name of granite, is familiar to to every one. Lofty mountain chains, sometimes rearing their Alpine summits far beyond the limit of perpetual snow, look down in solitary grandeur upon the scenes below. The hardest and most indestructable of all rocks, it seems fitted for the foundation or superstructure of the entire mass. Occasionally it is found of a more recent origin, exhibiting the appearance of having been ejected after the deposition of the newer strata; probably the result of intense heat acting under great pressure. We may suppose then that there was a time, "the beginning," when a globe existed having alternations of stone and water, no soil was upon its surface, which was a bare rock, presenting innumerable rugged peaks; not a sea-weed floated in the waters, nor a lichen grew on the rock; no sound was there except the monotonous and angry dash of the waves upon the bare and desolate coast. But even then, the atmosphere, perhaps surcharged with carbonic acid, was actively engaged in crumbling down the barren rocks, and we may suppose that the waves and the winds urged their combined force as now; the fragments of granite thus torn off, were deposited in the bed of the ocean, and we find them compacted under the name of gneiss. If during this action, the felspar was partly decomposed, then the quartz or silex, would be deposit-

ed alone, and subsequently the felspar and mica, either in the form of mica schist, which is composed of layers of mica and quartz, or slaty rocks without fossils; these are the strata which lying immediately upon the granite, and presenting marks of aqueous deposition, yet partake more or less of the crystaline character of the primitive rocks. During all the long period of the deposition of these rocks, formed from disintegrated granite, not a living thing moved, either on the dry shores or in the deep. Perhaps a few animalcules existed in the clear waters, but we have no distinct traces of them; all was silent, the stillness of absolute death. During this period however, great volcanic convulsions occurred, the yet soft masses of gneiss and schistose slates were upheaved, and in many cases rent open and molten masses of granite and basalt flowed through. The metals, melted by the intense heat, were injected into the narrow fissures, and innumerable dykes and veins were formed. In some instances the masses of melted trap rock have crystalized upon cooling, in regular hexagonal prisms. Such are the columns which compose the celebrated Fingal's Cave, exhibited in the wood-cut below.

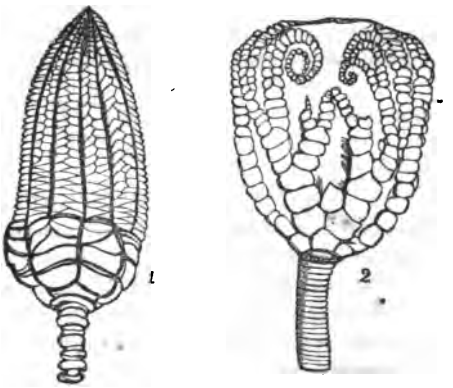
Directly associated with the contorted masses of mica schist to which we have just alluded, there is a coarse slaty rock, exhibiting still more clearly the marks of aqueous deposition, but by far the most interesting circumstance connected with this deposit, is the first appearance of animal life. We must consider with no little interest, the fossil remains of these early rocks; among

them are found peculiar species of shells, and a few corals, but as yet, nowhere throughout the whole world, in this immense deposit called the Cambrian, (page 191), has the least fragment been found referable to a fish; nor any traces of aquatic plants, except a few sea-weeds; nor vertebrated animals. It is therefore pretty evident, that at this time, either they did not exist, or if they did, it was in extremely small numbers. We find the lowest order of organization here developed, in the remains of a zoophyte, or animal plant figured below, which is analagous to the sea-pen,

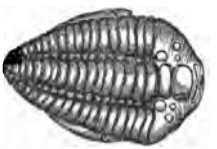


and termed by Mr. Murchison, who has investigated with great care, this series of rocks, *graptolites*, from the peculiar markings of the stone; these were probably formed by an assemblage of a vast number of individual polypes, each having a separate existence, but yet connected with the general mass, they are found in great abundance in the United States. There are also many species of coral common in the most ancient rocks, and similar in most respects to those now existing in the Indian Seas. The low organization of these coral polypes has probably enabled them to survive all the changes through which, so often the world has passed, and we find them at the present moment as busily employed as in the earliest periods of the earth's existence. The Silurian rocks are extensively developed over the whole world so far as geologists have been enabled to explore. The immense deposits of calcareous flags, sandstones, shales, and limestones, furnish our most valuable stones for economic purposes. As we advance upwards in the series of deposits we find a marked change not only in the mineralogical character, but in the number and form of the organic remains. Among the peculiar animals which flourished at this stage of the world's existence were

the Crinoidal, or lily-shaped animals, so called from a fancied resemblance to a lily, they are sometimes termed *Encrinites*. We here figure two specimens, one closed and the other open. There

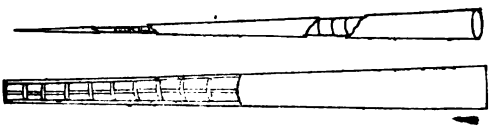


are a very great many varieties of encrinites, some of the most beautiful occur in the new red sandstone group, figure 1, is called the pear encrinite, fig. 2, the tuberculated; they consist essentially of a stony case, supported on a slender jointed stalk, and are found in all positions and in immense numbers, but they are of a much higher organization than the coral polype. Another very peculiar fossil of this epoch is the *trilobite*, so called from the body consisting of three distinct lobes. We here represent one of these animals; they are found in abundance in the



older strata, and of many distinct generic forms; they probably possessed short legs and were destitute of antennæ, the eye however, was the most remarkable feature. It was immovable, but to compensate for this it was exceedingly prominent and provided with many hundred lenses, precisely similar to the eye of the

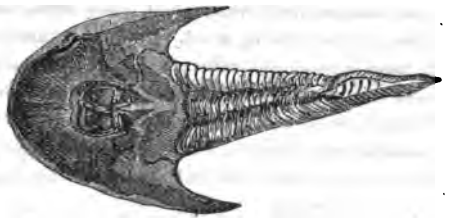
dragon-fly, and the house-fly. Among the moluscs, or soft bodied animals, we find one very common and characteristic of this period, but now entitely extinct, it belongs to the same family *cephalapoda*, i. e. having the arms or feet near or upon the head, as the nautilus, and is called the *orthoceratite*, or straight horned animal and is figured below, nothing is known of these



except the fragments of their former habitations, some of them are slender and pointed, others nearly straight, and they are occasionally found of great size. Such were the inhabitants of the globe during its early periods, while yet no fishes swam in its waters, or animals roved in forests upon the shore. Trilobites swarmed in innumerable multitudes; the crinoidal animals were attached to every fragment of rock; and the voracious cephalapoda roamed through the deep. Day and night then as now succeeded each other, and year after year passed on, but who can tell, or who can estimate the ages which rolled away from the commencement of the period we have been considering to the close of those immense deposits called the Silurian. But the dawn of a new era was now commencing, and the great and important natural class of fishes were about to be introduced, though with such marked peculiarities and singular forms, and so different from any now living that they almost seem allied to the crustaceans, or to the reptiles. One of the most singular, with long bony fins, is called the *Pterichthys Cornutus*, or horned winged fish. It was of small size, the head and body being covered with strong plates of bone coated with enamel. Another singular fish called *Cephalapsis*, or buckler-headed, possessed an enormous buckler head, similar to the cephalic shield of certain trilobites. It has been compared, and not unaptly, to the crescent shaped blade of a saddler's cutting knife, as will be seen on reference to the engraving on the following page.

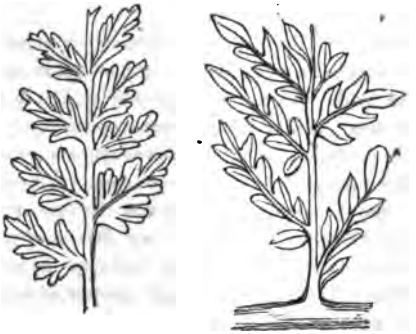
There are many other varieties or groups of fishes belonging

to this period which we cannot name here, but most of them belong to the two great classes designated by M. Agassiz, the Pla-



coid, or plated; and the Ganoid, or shining, or enameled. The first class, is at present represented by the sharks and rays, and the second by the sturgeon and bony pike. The former or Placoid, were first introduced, but were comparatively small and feeble, but the latter, during the Devonian, or old red sandstone period, (see page 190), were very abundant. It is somewhat remarkable that this group of fishes is now represented by only two species, the American Gar-pike and the Birchir of the Nile; no less than sixty distinct species being found in the old red sandstone. No traces however, of those groups of fishes, now so abundant, are found in these strata. Leaving this remarkable period, when the waters teemed with formidable and singular shaped fishes, we find the commencement of a new epoch in the appearance of an immense deposit of carbonate of lime, in the form of the carboniferous or mountain limestone, and the variegated marbles; imbedding a remarkable number of vegetable fossils, which indicate not only the presence of land, but the existence of a luxuriant and tropical vegetation. The carboniferous limestone, is in many cases the result of the labors of the coral insect, indicating the presence of a shallow sea-bottom and warm temperature. Immediately in contact with the coraline limestones is a coarse sandy conglomerate used for millstones, and called the mill-stone grit, which is succeeded by strata of shale and sandstone, with occasional seams of coal; after which, follow the coal measures, so called, being large deposits of bituminous coal. But little doubt can exist as to the vegetable origin of all coal; it is true that the most perfect bituminous coal has under-

gone a liquefaction which has destroyed its organization, but in the slaty coals and the shales, traces of cellular tissue are observed, and the peculiar spiral vessels and dotted cells, indicating the coniferous or cone-bearing wood. We must therefore conclude that these beds of coal, although mineralized, and almost crystaline in their appearance, are entirely of vegetable origin. Among the fossils of the coal there are a great variety of ferns, and some of them of very elegant forms. We here give figures of two species, fig. 1, is from the coal shales of Ohio, called the



2 1

Pecopteris Sillimani, or Silliman's embroidered fern; and fig. 2, the *Sphenopteris*, or wedge-leafed fern; from the coal shales Silesia. Besides the fern tribe, which in the ancient world seems to have been much more largely developed than at present, we find gigantic specimens of the Calamite, similar in all respects to the common reed growing abundantly in our marshes and called *Equisetum*, or marestail.

Notwithstanding the extensive beds of coal found everywhere over the globe, no trace or fragment of quadruped, bird or reptile, has been discovered. The immense forests of aborescent or tree ferns, and coniferous trees with their rich and luxuriant vegetation, were desolate and silent; no reptile crawled over the damp ground, no bird made a nest among the green foliage, no sound broke the primeval silence, which for ages shrouded the the thick forests; silently they sank down beneath the waters, and

in the lapse of ages other strata enveloped them, and preserved the forms of their delicate leaves, and the markings of their trunks and stems, for the inspection of long succeeding ages. But all this time the sea was alive with its multitudes of corals, of echini, trilobites, and peculiar cephalopods, and fishes. It was during this epoch, that the ganoid fishes were most highly developed, and innumerable sharks of all sizes abounded in the carboniferous seas.

We have now arrived at the end of our first epoch, just before the introduction of reptiles. There seems in some respects to have been a progression in organization, and yet, not such as to support the view, however plausible, of the agency of an inferior type of organization in introducing a higher group. The corals and the encrinites still remained with but little change, but the trilobites were nearly extinct, the cephalapodous animals, retaining till now the straight and elongated form of the orthceratites, assumed the spiral form of the goniatite. The small fishes of the early epochs gave place to large and voracious species, powerful swimmers and insatiably voracious; vast tracts of country were settling down, and the rich and rank vegetation, which covered the land at the time of the coal epoch, was prepared for the first stage of its change into coal. During all this period, we must not fail to note the entire absence of all the grasses, which now form so prominent a portion of existing plants; indeed, the whole face of the globe, was so entirely different from its present appearance, that could we now behold it, we might realize that we were looking upon another planet. It is not for us to discuss the question of the length of time necessary to accomplish all those changes which the globe has passed through, or to speculate upon the distinct efforts of creative power exhibited throughout those countless ages. It is sufficient for us to know that myriads of beings, dissimilar to any now existing, or only remotely connected, flourished perhaps for thousands of years, when suddenly they disappeared, and quite as suddenly new forms replaced those lost. There can be no way of accounting for these changes in the forms of animal and vegetable life, except by the direct interposition of a creative power.

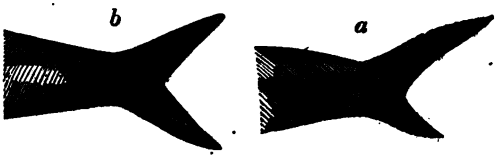
CHAPTER XIV.

The second Epoch.

"And later yet the sea o'erspread
The spot where now we walk;
And this was once an ocean's bed,
The ocean of the chalk." *Anon.*

THE epoch now to be considered, is in many respects the most interesting, as it is certainly the most abundant in its fossil remains. In our present volume we can only glance at the charteristic features, leaving wholly untouched those minor details, which often make the most interesting part of a history. We can therefore only hope that the reader will make a beginning here, but search elsewhere for more extended and minute information. Immediately above the coal measures, lies a coarse sandy deposit, which appears to be the ruins of some more ancient rock, consolidated by pressure and the infiltration of water impregnated with iron. The shores of the previously existing lands, seem to have gradually been depressed, forming vast beds of coal; upon these, the beds of sand and marl were loosely and rapidly deposited, and are not exceedingly rich in their fossil remains. There is however, one interesting and remarkable fact connected with these deposits, and that is, distinct tracks of reptiles and birds; to these we shall allude again presently. The lowest member of the new red sandstone group is the magnesian limestone, so called from having a considerable portion of carbonate of magnesia mixed with its carbonate of lime; it is a stone exceedingly valuable for building purposes. This limestone contains a few fossils, corals and shells, and occasionally a few fragments or whole skeletons of fishes. The fishes are all remarkable for a peculiar structure of tail characteristic also of the fishes of the older strata, this structure is called by M. Agassiz the hete-

rocercal, the tail being unequally lobed as in fig. 1, which is the tail of the shark, and the vertebral column running along the upper lobe. On the other hand, in nearly all the living species,

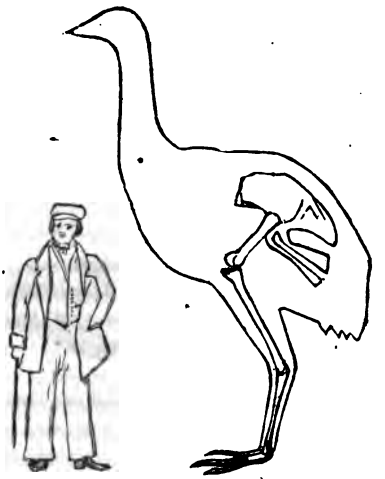


the tail is homocercal as in fig. 2, which is the tail of a herring, the vertebral column not extending to the upper lobe.

We have remarked that the first tracks of reptiles are met with in this system of deposits. Below we represent the appearance of these footprints as observed in England and Germany. It

will be perceived that there are two impressions which always accompany each other, and they are not unlike the human hand, hence the animal was named *cheirotherium* or hand beast. This animal was for a long time supposed to be allied to the kangaroo, and like it a marsupial, *i. e.* having a pouch in which to carry its young; but more recently Prof. Owen, from a careful examination of teeth and other bones found in the new red sandstone, has determined it to belong to the class of batrachians, or frogs, toads, salamanders, &c., and from the peculiar structure of its teeth, he has given to this genus the name *labyrinthodon*, or labyrinth tooth. Besides the tracks just described, are found those of turtles, of a little lizard with a bird-like beak, and the trails of molluscs, and vermes, and the ripple marks of the ancient seas. By far the most remarkable tracks occurring in the new red sandstone group, are those of gigantic birds, the foot-prints being seventeen inches long, and the stride of the bird from four to six feet. It is somewhat remarkable that nearly all the fossil foot

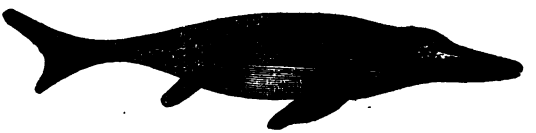
marks yet discovered, occur upon some member of the new red sandstone group. On the same stone are impressions of rain drops. "It is a most interesting thought," observes Prof. Hitchcock, "that while millions of men who have striven hard to transmit some trace of their existence to future generations, have sunk into utter oblivion, the simple footsteps of animals, that existed thousands, nay, tens of thousands of years ago, should remain as fresh and distinct as if yesterday impressed; even though nearly every other vestige of their existence has vanished. Nay still more strange is it, that even the pattering of a shower at that distant period, should have left marks equally distinct, and registered with infallible certainty the direction of the wind." When these foot prints were first discovered their enormous size seemed an insuperable objection to the opinion that they were bird tracks. But recently in the island of New Zealand, the bones of an immense wingless bird have been found to which the name *Dinornis*, or terrible bird, has been given. Below is an outline representing the size of this extraordinary animal compared with a man.



Immediately above the new red sandstone in some parts of the

world, but particularly in England, is deposited a fine sandy and marly stratum, consisting of distinct layers with occasional limestones, and exceedingly abundant in remarkable fossil remains. To this the name Lias has been given, and the reptilian remains imbedded in it are the most magnificent objects of the Creator's hand. During the deposit of these muddy beds which were unfavorable to the growth of corals, we find but few traces of these animals, but on the contrary the crinoidea, already alluded to, were developed in singular and beautiful forms, and also very peculiar forms of the cephalapodic group. Among the marine reptiles of the epoch we are now considering, two are particularly noticeable. The *Plesiosaurus*, or almost lizard, and the *Ichthyosaurus*, or fish lizard. Below we represent the plesiosarus, which possesses a head small, and lizard-like, with teeth like a croco-

dile, a neck of enormous length like the body of a serpent, and a back and tail having the proportions of an ordinary quadruped. It is furnished with four paddles, and is supposed to have inhabited the shallow waters; darting by means of its long neck, suddenly at the fish which came near it. The largest complete specimen of the plesiosarus yet discovered is about eighteen feet in length. Fierce and voracious as this animal undoubtedly was, yet it had an enemy in the ichthyosarus represented in the following wood cut. This formidable marine reptile sometimes attain-



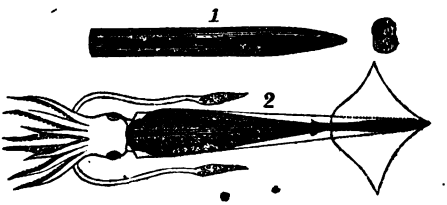
ed to a length or thirty or forty feet, and like the whale possessed a smooth and naked skin. The eyes were enormously large and provided with bony plates, or divisions arranged around the pupil. There are instances where the diameter of the orbit is eighteen

inches across. The jaws are long and furnished with sharp conical teeth, resembling those of the crocodile, and like them replaced continually, as they become worn, by new ones; the fins or paddles were four. Both these remarkable animals, now entirely extinct, are figured in the frontispiece of the present volume, which is designed to represent the condition of our globe during the period we are now considering.

Above the lias shales is a deposit which seems to indicate great changes in the organic world, caused by the elevation of wide tracts of country over certain portions of the globe, attended with numerous depressions in other parts, and the strata deposited during these movements seems to have formed the bed or final depository of many successive races of beings. The name Oolite given to this group of deposits signifies egg-like stone, because it is formed of small egg-like grains, like those comprising the roe of a fish, the nucleus of which, on microscopic examination, appears to be some minute organic substance, usually a fragment of coral, or a shell. To this class belong the so-called Oxford and Kimmeredge clays, and the Jura limestone, since the mass of the Jura mountains in France is of the oolite formation. During this period, an immense number of marine animals flourished, most of which are now entirely extinct, among them are peculiar corals, star-fishes, and sea-eggs or echini. Below we give a representation of a very perfect crustacean, similar to the

lobster, from the oolite clay of Yorkshire, England. The fossil remains of insects are also common in these strata, and very peculiar and beautiful forms of ammonite, which seems to have

been most perfectly developed in the lias seas. We have before described a cephalapod called the orthoceratite, (page 306), subsequently we find this animal displaced by one with a curved and somewhat angular shell during the carboniferous formation, still later during the deposition of the lias and oolitic beds, we find another change under the form of the ammonite; at the same time the nautilus, a well known cephalapodous animal, closely related to the ammonite, was likewise abundant. The nautilus still inhabits our tropical seas, and unfolds its fleshy sails to the gentle breezes, but long since the ammonite has been extinct. Another of the same class or group of animals, and which is now represented by the cuttle-fish, is the animal of the belemnite. The fossil called the *belemnite* from its resemblance to a dart or javelin, is not uncommon, and is found of various lengths and is



sometimes called by the singular names of the devil's toe-nail, thunderbolt, &c.; the general appearance of the fossil is however as represented in fig. 1, and perhaps no organic remains have ever caused more ludicrous mistakes, or given rise to more fanciful theories. It is the internal skeleton of an animal very much like the cuttle-fish, and represented in fig. 2. From the fossil remains, this animal appears to have been exceedingly large and formidable, preying upon the smaller fishes and reptiles, it was furished with eight long arms, each provided with from fifteen to twenty hooks; the eyes were large and the jaws powerful. Like the common squid, it seems to have been provided with an oval sac, containing a dark fluid, ejected by the animal when alarmed in order to discolor the water and facilitate its escape. During

this period the plesiosaurus, and the ichthyosaurus abounded, and in addition we find another marine monster rivaling the largest whales in size, possessing webbed feet armed with strong claws.

The flora of the carboniferous period, we have observed, consisted mostly of ferns, and large coniferous trees, of gigantic dimensions, and of calamites, and numerous other plants the exact nature of which is not yet determined; but in the lias and oolitic formations an entirely new race of plants covered the earth. The ferns, which formerly constituted two-thirds of the entire species known, were greatly diminished, and the calamites and palms all disappear. Coniferous plants were still very common, but of different species from those of the earlier epochs, and plants analagous to the Cycadeæ and Zamias of the tropical regions seem to have replaced the ferns. The wood cut will give a tolerable idea of the character and appearance of the flora of

the oolitic period. During this Age of Reptiles, as it has been termed, one of the most marvellous beings, and which for a long time caused no little speculation and discussion among philosophers, flourished in considerable numbers. It has been termed the *Pterodactyle*, or wing-toed animal. (See next figure). This flying reptile, possessing the head of a bird, the wings of a bat, and the body and tail of an ordinary mammalian, appears to be a

sort of connecting link between the three great groups, reptiles,

birds, and mammals. It seems to have been capable of walking with ease upon the ground, of perching on trees, and of flying swiftly through the air. The teeth of the pterodactyle are long, pointed, and slender, from twenty to thirty in each jaw, and like the crocodile replaced by new ones when worn.— While the calcareous oolitic beds were being deposited in the sea, there seems to have been in some parts of the world, but particularly in the southern part of England, immense rivers, with extensive estuaries flowing over vast tracts of countries, and bearing down upon their waters and imbedding in the mud and silt of the shoaling estuaries, the remains of land plants and animals, and fresh water shells. To the beds or deposits thus made, the name Wealden has been given, (see page 188). With the exception of the plants of the coal epoch, this deposit is almost the sole evidence of the ancient land and its inhabitants. It is somewhat remarkable that among all the previous deposits no trace of any true quadruped has been found, all the remains belong to marine or land reptiles, and up to the time of the Wealden formation no traces except the few tracks on the new red sandstone, are found of birds. Dr. Mantell, who has so successfully investigated the geology of the south-east of England, has however in the latter named strata, discovered many fragments of bones supposed to

belong to birds allied the Herons. Among the reptiles characteristic of this deposit the most remarkable is the Iguanodon, so called from the resemblance of its teeth to those of the Iguana, a recent West Indian lizard. This gigantic suarian, or lizard, was upwards of 70 feet in extreme length; the circumference of body 14½ feet; length of tail 52½ feet; and of the hind foot 6½ feet. In the British Museum, is a thigh bone of an Iguanodon, which is 3 feet in length, and eight inches in diameter. We cannot easily conceive of a reptile of such huge dimensions; surpassing in height the tallest elephants, and far greater in bulk than any known living animal. A reptile of the same class, called the Hylæosaurus, or lizard of the Weald, was likewise discovered by Dr. Mantell; in dimensions it was somewhat less than the iguanodon, and armed with a row of spiral protuberances, and scaly plates.

During the deposit of the chalk, a vast multitude of fishes swarmed in the waters, among these were immense sharks, whose remains are plentifully found. How different the scenes then enacted, both on land and in the sea, from now. While upon the land, gigantic reptiles prowled through the dark woods, or along the chalky shores, covered with alligators and turtles; and the pterodactyle glided swiftly amid the dark foliage in pursuit of its prey; the ichthyosaur, the plesiosaur, and voracious sharks roamed through the deep, devouring multitudes of smaller animals. Upon the surface of the waters, the nautilus and ammonite still sailed, and the sea egg rolled over the smooth bottom. Then, as now, the coral insect toiled on, and thousands of encrinites waved their flexile stems in the heaving waters. Scenes like these, for ages, were witnessed upon the face of our planet, but we cannot begin to estimate the lapse, not of years or centuries, but of myriads, ere the change came which swept them forever from among the living things of earth, entombing them for memorials of those remote ages, which should tell in language too plain to be misunderstood, that many times, since the earth first commenced its revolution around the sun, changes have passed over its surface which would be more than sufficient to sweep away every living thing which now moves upon it.

CHAPTER XV.

The Tertiary Period.

"Yes! Where the huntsman winds his matin horn,
And the couch'd hare beneath the covert trembles;
Where shepherds tend their flocks, and grows the corn;
Where Fashion on our gay Parade assembles —
Wild Horses, Deer, and Elephants have strayed,
Treading beneath their feet old Ocean's races."

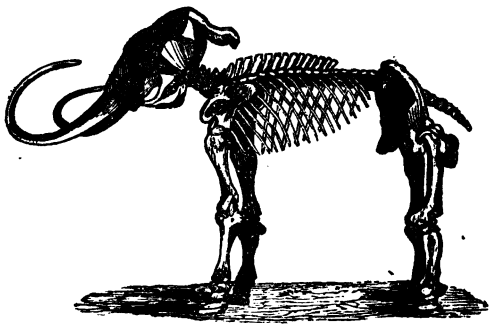
Horace Smith.

We are now to consider the last great epoch, called the tertiary period, commencing immediately after the deposit of the chalk, and ending with the appearance of man. The tertiary strata consist of a vast and varied series of deposits, fluviatile, lacrustine, marine and volcanic, but they are all deposited in hollows or depressions, usually of the chalk, and occasionally of the older rocks, and afford distinct evidence of important changes in the relative level of land and sea, during the period in which they were deposited, and they likewise show that volcanic agency was developed at this period on a vast and magnificent scale. From the remains entombed during this epoch, it is pretty evident that the climate of the ancient world was much milder than at present. Be this as it may, it is a fact indisputable, that not only the bones of hyenas, bears, lions, and tigers, are found in countries where now they could not live, but also several varieties of palms and pines; and even as far north as the 70° of latitude, the remains of the elephant and rhinoceros are found imbedded in the ice. During the tertiary epoch, the Ganoid and Placoid groups of fishes, so characteristic of the earlier deposits, were almost extinct, the latter class being represented by a few sharks and rays, while by far the greater number were allied to existing species. The remains of birds; skeletons, feathers, and even their

eggs, are found in good preservation—they are allied to present existing species. On the island of New Zealand, an immense number of fossil bones of birds have been found; we have already alluded to one of these, the Dinornis, page 312; the beak of this bird was shaped like a cooper's adze, and admirably adapted for tearing up roots; they were, as Dr. Mantell remarks in a letter to Prof. Silliman, "glorious bipeds, some ten or twelve feet high." In the tertiary strata of the Paris basin, Cuvier found the remains of several thick skinned animals allied to the tapir, and of others forming a connecting link between the tapir and the ruminants, or animals chewing the cud—some of these were of very peculiar forms. A remarkable animal, characteristic of the middle tertiary period, was the *Deinotherium*, or terrible beast, figured in the engraving below This huge animal dwelt probably in

marshes and swamps, and was nearly twenty feet long; the legs are supposed to have been nearly ten feet in length, the head was of proportional size, and furnished with two large tusks fixed in the lower jaw, which probably, served the purpose of pickaxes, to dig out the roots upon which it fed, and perhaps to anchor it by the side of the bank at night. In Russia and Siberia, remains of the elephant and rhinoceros have been found entombed in ice, together with birch trees, far beyond where even stinted bushes now grow. The tusks of the fossil elephants are found in the high hills above the sea level, in clay and sand frozen as hard as a rock, and increasing in abundance as we proceed north. For about a century they have been brought away in immense num-

bers, yet with no perceptible diminution of the stock; doubtless many of these animals were drifted down towards the arctic seas by the immense rivers which flow northward into the icy ocean. The subjoined figure represents the skeleton of the celebrated elephant discovered by a Tungusian fisherman, in the year 1790, in the banks of a river in Siberia, in which it had been frozen up for ages. The skin of this animal was of a dark grey color, and



covered with reddish wool. The two tusks, together, weighed three hundred and sixty pounds, and the head alone, four hundred and fourteen pounds; the flesh of this antediluvian was in such perfect preservation, that the dogs, white bears, wolves and foxes fed upon it. The eyes were well preserved, and the pupil in one of them could be distinguished. The fossil Siberian elephant differed but little from the one now inhabiting India, except in its wooly covering; its food was probably twigs and branches, in pursuit of which, herds of these gigantic quadrupeds probably migrated far north. The remains of elephants are very widely distributed; they are found in England and various parts of America; the teeth of the elephant may be readily distinguished from those of the mastodon, another large hebiverous animal belonging to this period, by a peculiar structure we will now describe. We here represent the teeth of the recent and fossil elephant; *a* the African, *b* the Indian or Asiatic, *c* the Siberian or fossil. In the first variety, *(a)* the enamel is arranged in lozenge-shaped figures, and in the second *(b)* in narrow transverse bands, very

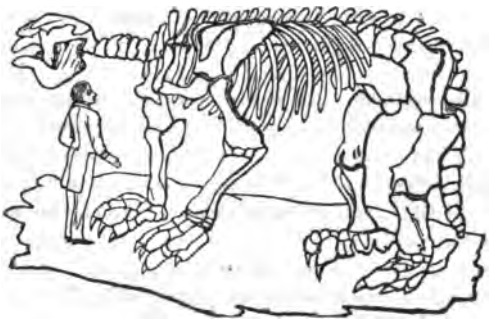
similar to the fossil species *c;* these teeth are composed of three

a *b* *c*

different substances; the enamel, exhibited by the white lozenges or bands, and which extends quite through the tooth to the roots; the ivory inside of the lozenges, and the *crusta petrosa* or stony crust outside. The tooth of the mastodon represented below, consists of ivory and enamel only; the enamel being spread

over the crown of the tooth, its structure is similar to that of the hog and hippopotamus, fitted for bruising and masticating crude vegetables and roots. The bones and teeth of the mastodon are found all over North America, and many entire skeletons have been exhumed, in some of which, the remains of branches and twigs undigested have been found. The remains of these animals are particularly abundant in those marshy tracts, abounding in salt and brackish waters called *licks.* The mastodon was not unlike the elephant, but was somewhat larger, and probably

much more powerful. While in England and various parts of the eastern continent, the elephants were congregated in immense numbers, and the plains of North America covered with herds of mastodons, another and more singular animal, allied to the sloth, lived in the forests of South America; we refer to the *Megatherium*, or great beast. In the museum at Madrid, there is a perfect skeleton of this animal, whose massive proportions strikes the beholder with astonishment; it is represented in the wood-cut below, and the proportions will be recognized on



comparing the figure with that of an ordinary sized man, drawn to the same scale. Its length is nineteen feet, breadth across the loins, six feet, and height, nine feet. The feet of the hind legs set at right angles, as in the bear; the heel projects behind, fifteen inches, and the toes, armed with long claws, about twice that distance forward: so that a proper base is afforded for the support of the immense body. The teeth of the megatherium were constantly renewed. This apparently unwieldy animal is allied to the sloth, but differs from it in the immense strength and massiveness of its posterior portions. It is supposed they fed upon the foliage of trees which they were enabled to uproot by their immense strength. This idea is confirmed from the fractures of the skull observed in some of the specimens. Contemporary with the megatherium, were several other allied species, which ranged through the luxuriant forests of South America, while in England

were herds of deer and wild elephants. In Ireland, the fossil remains of an enormous deer, surpassing the largest elks in size, are found imbedded in the peat bogs. The expanse of the horns in some of the specimens is sixteen feet. There is reason to believe that this animal, though now entirely extinct, existed after the introduction of the human race, since skulls have been found fractured in front, as by the blow of some heavy weapon, and associated with artificial remains. The small Irish ox, or bison, was probably identical with the auroch of Lithuania, which is only preserved from utter extermination by a stringent ukase of the Czar. At the same time, most of the existing species of animals and vegetables flourished in great numbers. The earth was teeming with life and fitted for the habitation of man. The various races which from time to time succeeded each other on our planet, had performed their allotted tasks. The whole system uniformly and without interruption, seems to have been matured. The light soil deposited upon the harder rocks, and in the hollows of ancient lakes, was gradually elevated, forming the present continents and islands. How long the present stage of the earth's existence may last, no one can pretend to answer. In all the changes which have heretofore swept races of highly organized beings from the face of the globe, we see the quiet action of laws now in force; no sudden catastrophe is needed, but silently the change goes on.

> "The Earth has gathered to her breast again,
> And yet again, the millions that were born
> Of her unnumbered, unremembered tribes."